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HER WORLDS THAN OURS

THE PLURALITY OF WORLDS
STUDIED UNDER THE LIGHT OF SCIENTIFIC
RESEARCHES

T P L
STOCK WEEDED
1099

BY

RICHARD A. PROCTOR

> Not to this evanescent speck of earth
> Poorly confined—the radiant tracts on high
> Are our exalted range; intent to gaze
> Creation through, and from that full complex
> Of never-ending wonders, to conceive
> Of the Sole Being right
>
> [illegible]

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39 PATERNOSTER ROW, LONDON
NEW YORK AND BOMBAY
1899

FROM THE

REFACE TO THE FOURTH EDITION.

DITION has been carefully revised, and in many
ant respects modified.

veral passages relating to questions which were
controversy when the earlier editions appeared
een removed,—those questions having been
d by new evidence, in the sense advocated in
ginal text.

ave also omitted several passages from the last
r, as expressing a more confident opinion about
s connected with the supervision and control
universe than I at present entertain.

RICHARD A. PROCTOR.

FROM THE

REFACE TO THE SECOND EDITION.

ONG the additions which have been made to the
contained in a former edition are two which
some notice.

e first consists of new evidence against the
that the cloud-belts of Jupiter and Saturn
sed by the sun's heat. I find it difficult to
e how this evidence can be interpreted other-
han by the theory that the belts of the giant
are generated, maintained, and modified by
nherent in those planets, and not by any action
l from without.

e second is the matter contained in pp. 264,
74–279, and illustrated by the large plate
p. 275. Rightly understood, the evidence

1. *Within the limits which include the stars* ***visible*** *the naked eye there are* ***laws of aggregation and*** *regation which the theories hitherto* ***accepted respect-*** *the fixed stars wholly fail to account for.*

2. *The Milky Way is not, as has been* ***so long*** *posed, a stratum of stars of all orders* ***extending*** *distances very far exceeding,* ***relatively as well as*** *itively, the distances of the lucid stars,—****but is a*** *um of small stars, amidst which* ***many of the lucid*** *rs are immersed.* These points seem to be as pletely demonstrated by the evidence adduced as tions of the sort can ever be.

Richard A. Proctor.

ONDON: *October* 1870.

EXTRACTS FROM THE

PREFACE TO THE FIRST EDITION.

On many of the subjects dealt with in this work, I have propounded views which differ from those usually accepted. Each of the new views here presented has been the result of a careful study of the subject dealt with, and I have searched as anxiously for considerations opposed to any novel theory, as for arguments in its favour.

My theory respecting the sidereal system has been based on the signs of systematic aggregation among the lucid stars, and of a more intimate association of those stars with the Milky Way than could be expected were Sir William Herschel's fundamental theory correct.

The theory brought forward in the chapter on Meteors and Comets is not altogether new. The general idea on which it is grounded has been dealt with by Mayer and Thomson. The idea, however, presented itself independently to my mind when I was writing my treatise on Saturn. The line of reasoning is wholly new, I believe, by which I have endeavoured to show that those peculiarities of the solar system which have hitherto been regarded as affording the strongest objection to the hypothesis of development, may be regarded as in reality the direct result of the processes by which the solar system has reached its present condition. In the preface to my treatise on Saturn I touched on the possibility that some such explanation of those peculiarities might be found, remarking that in the rings of Saturn astronomers may one day recognise the action of the processes by which the solar system has attained its present state.

RICHARD A. PROCTOR.

LONDON: *May* 1870.

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OTHER WORLDS THAN OURS.

INTRODUCTION.

STRONOMY and GEOLOGY owe much of their charm to e fact that they suggest thoughts of other forms of e than those with which we are familiar. Geology aches us of days when this earth was peopled with range creatures such as now are not found upon its rface. We turn our thoughts to the epochs when ose monsters throve and multiplied, and picture to rselves the appearance which our earth then pre- nted. Strange forms of vegetation clothe the scene hich the mind's eye dwells upon. The air is heavier den with moisture to nourish the abundant flora; deous reptiles crawl over their slimy domain, battling th each other or with the denizens of the forest; ge bat-like creatures sweep through the dusky ilight which constituted the primeval day; weird onsters pursue their prey amid the ocean depths: d we forget, as we dwell upon the strange forms hich existed in those long past ages, that the scene

w presented by the earth is no less wonderful, and
at the records of our time may perhaps seem one day
perplexing as we now find those of the geological eras.

Astronomy has a kindred charm. We cannot in-
ed examine the actual substance of living creatures
xisting upon other celestial bodies; we cannot pic-
re to ourselves their appearance or qualities; and
nly in a few instances can we even form any con-
ption of the conditions under which they live. But
see proofs on all sides that, besides the world on
hich we live, other worlds exist as well cared for and
nobly planned. Nay, we see globes by the side of
hich our earth would seem but as a tiny speck; we
ce these globes as they sweep with stately motion
their appointed courses; we watch the return of
y on the broad expanse of their surface; and we see
stems of satellites which are suspended as lights for
eir nocturnal skies. We further find that our sun is
atched by a thousand thousand suns amid the im-
easurable depths of space; and the mind's eye pic-
res other worlds like those which course around the
n, travelling in stately orbits around his fellow
minaries.

Long, however, before the wonders of modern astro-
omy had been revealed to us, men of inquiring minds
em to have been led, as by an irresistible instinct, to
amine into the resemblance which may exist between
r world and other worlds surrounding it on every
de. It has not been the mere fanciful theoriser who

eminence in science. In long past ages Anaximander and Pythagoras studied the subject of other worlds than ours; later, such men as Huyghens, Galileo, and Newton have dwelt upon the same interesting theme; while, in our own day, Whewell and Brewster have employed their scientific and dialectic skill in defending rival theories upon the subject.

Undoubtedly, a large share of the interest with which the question of other worlds than ours has been regarded is due to the fact that, as the science of astronomy has progressed, the subject has continually presented itself under new aspects. The question, in fact, is one of those which are ever new and ever old. It has all the charm belonging to subjects which men in all ages have delighted to discuss, while it is associated in the most intimate manner with the progress of modern scientific research. The discoveries which are made by astronomers acquire a new interest when they are associated with the subject of life in other worlds. The interest with which the public regard many of those discoveries may, indeed, be said to depend wholly on their bearing upon this subject.

We stand in a position much more favourable for the formation of just views on the subject of life in other worlds than that from which men surveyed the planetary and stellar systems thirty or forty years since. Never, since men first explored the celestial depths, has a series of more startling discoveries rewarded the labours of astronomers and physicists than during the past few years. Unhoped-for revelations ave been made on every side. Analogies the most iteresting have brought the distant orbs of heaven ito close relationship with our own earth or with the entral luminary of the planetary scheme. And a esson has been taught us which bears even more gnificantly on our views respecting the existence of her worlds: we have learned to recognise within the olar system, and within the wondrous galaxy of which ır sun is a constituent orb, a variety of structure and complexity of detail, of which but a few years ago stronomers had formed but the most inadequate onceptions.

My object, then, in the pages which follow, is not olely to establish the thesis that there are other worlds ian ours, but to present, in a new and, I hope, interesting ght the marvellous discoveries which have rewarded ecent scientific researches. Judged merely according o their direct significance, these discoveries are full of iterest. But it is when we consider them in their elation to the existence of other worlds, when we tempt to form a conception of the immense varieties f the forms of life corresponding to the innumerable arieties of cosmical structure disclosed by modern esearches, that we recognise their full significance. lthough the growth of our knowledge is ever accompanied by a proportional growth of our estimate of the nknown, we seem already entitled to say that we have

> Come on that which is, and caught
> The deep pulsations of the world,

CHAPTER I.

WHAT OUR EARTH TEACHES US.

ORE proceeding to consider the various circum- ces under which the worlds or systems which und us appear to subsist, it may be well to ire how far we have reason to conclude, from the deration of our own earth, that other orbs in support life.

t would not be just to argue directly from the fact the earth is inhabited to the conclusion that the plauets are inhabited also, nor thence to the con- on that other stars have, like our sun, their attend- worlds, peopled with various forms of life. An gy founded on a single instance has no logical . And it is doubtful whether we have not, in the , an instance which would as effectually serve to ort a directly opposite conclusion. It seems all certain, as we shall presently have occasion to , that no part of the moon's globe is inhabited by creatures. Certainly she is inhabited by none

e of the two orbs respecting which we know most
pears to be uninhabited, there remains no probable
gument in favour of the view that other orbs besides
r earth are the abode of living creatures.

Yet the earth in reality supplies an argument of
eat force, when we consider the evidence she pre-
nts in another light. The mere fact that this world
inhabited is, as we have seen, little; but we shall
d that the way in which life is distributed over the
rth's surface is full of significance.

If we range over the earth, from the Arctic regions
the torrid zone, we find that none of the peculiarities
hich mark the several regions of our globe suffice to
nish life from its surface. In the bitter cold within
Arctic Circles, with their strange alternations of long
mmer days and long winter nights, their frozen seas,
rennial ice, and scanty vegetation, life flourishes in a
ndred various forms. On the other hand, the torrid
ne, with its blazing heat, its long-continued droughts,
strange absence of true seasonal changes, and its
ying alternations of oppressive calms and fiercely
ging hurricanes, nourishes even more numerous and
re various forms of life than either of the great
mperate zones. Around mountain summits as in the
pth of the most secluded valleys, in mid-ocean as in
e arid desert, in the air as beneath the surface of the
rth, we find a myriad forms of life.

But this is far from being all. Various as are the
ysical habitudes which we encounter as we travel

existence of other varieties even more remarkable. The geologist has been able to turn back a few leaves of the earth's past history, and though the pages have been defaced and mutilated by Time's unsparing hand, he is yet able to read in them of many strange vicissitudes to which the continents and oceans of our globe have been exposed. But, far back as he can trace the earth's history—and already he counts her age by millions of years—he finds no evidence of an epoch when life was absent from her surface. Nay, if he reads aright the mysterious lesson which the blurred letters teach him, he is led to believe that, at the most distant epoch to which his researches have extended, there was the same wonderful variety in the forms of life as at the present day. He can, indeed, find the scattered remains of only a few of those old-world creatures; but he recognises in those which have been preserved the clearest evidence that thousands of others must have existed around them. He knows that of a million creatures now existing scarcely one will leave to future ages any record of its existence; he sees whole races vanishing from the earth, leaving no trace behind them; and he is thus able to form an estimate of the enormous extent by which the creatures and races of which he can learn *nothing* must have outnumbered those whose scattered remains attest their former existence upon the earth.

Here, then, we have analogies which there is no mistaking. We see that not only is Nature careful to fill all available space with living forms, but that no

ne over which our researches extend has found her
s prodigal of life. We see that, within very wide
its, she has a singular power of adapting living
atures to the circumstances which surround them.
r is this lesson affected—like the general lesson
wn from the mere fact of the earth's being inhabited
by anything we can learn from the aspect of our
ellite. For the arguments against the presence of
ng creatures on the moon are founded on the evi-
ce we have that the physical habitudes of that orb
outside the limits within which Nature effects the
ptation spoken of.

The moon teaches us, however, that all the celestial
ies are not at all times habitable. The sun also
ches the same lesson. And it is necessary that we
uld consider how far the evidence presented by our
earth may serve to elucidate this teaching. We
ll see that terrestrial analogies afford a very sure
de in the midst of many perplexities presented by
study of the worlds around us.

Let us trace out the various degrees of fitness or un-
ess for the support of particular forms of life, which
recognise in various regions of our earth.

Often, where there exists so slight a difference be-
en two regions of the earth that, to ordinary obser-
ion, it would appear that the forms of life existing
ne should be well adapted to the other also, we yet
l that this is not the case. Some minute peculiarity
oil, or climate, or vegetation, will render one region

thrives in the other. Darwin mentions several instances in which an apparently insignificant change in the circumstances under which a particular race has thriven, and sometimes a change which does not, at first sight, appear to be in the least connected with the well-being of the race, has led to its gradual disappearance. And it seems demonstrated that even the slow processes of change to which every part of the earth is subjected would suffice to destroy a number of the races now subsisting on its surface, were the characteristics of those races unalterable. But as the physical habitudes of their abode slowly change, the various races of living creatures slowly change also, so as to adapt themselves continually to the varying circumstances under which they live.

The lesson taught us by this peculiarity is very obvious. On the one hand, we see that it would be by no means sufficient to indicate a general resemblance between the physical habitudes of our earth and those of some far distant planet, in order to prove that that planet is the abode of living creatures resembling those on our own earth. But, on the other hand, we are taught that the existence of differences sufficient to render a distant planet an unsuitable abode for such creatures as we are familiar with cannot force upon us the conclusion that the planet is uninhabited. On the contrary, the circumstance we have been considering teaches us that such differences as would suffice to banish life of certain kinds are insufficient to banish life of all kinds, or even to render less abundant the ms of life which exist under those changed condins.

And now we may proceed a step farther. On our th we find differences of climate and of physical pitudes generally, which are much more important n those hitherto dealt with. We see that not only uld certain races perish in the long run, if removed m their own abode to other parts of the earth, but t, in some instances, the process of destruction would very rapid indeed. If we were to remove the polar rs from their Arctic fastnesses to tropical, or even the warmer parts of temperate regions, a very few rs would see the end of the whole race. The races abiting steppes and prairies would quickly perish if noved to mountain regions. Those accustomed to a isture-laden air and abundant vegetation would not vive long if removed to the desert.

In some races, indeed, we find a power of enduring h changes which very far exceeds that possessed by er races. Those creatures, for example, which man s domesticated seem capable of enduring a variety climate or of circumstances, which would destroy seemingly more vigorous races not yet subdued to yoke of man.[1]

[1] Humboldt tells us that 'the pliability of the organisation of se animals which man has subjected to his sway enables horses, rs, and other species of European origin to lead for a time an phibious life, surrounded by crocodiles, water-serpents, and manas. When the rivers return again to their beds, the horses n in the savannah, which is then spread over with a fine riferous grass; and enjoy, as in their native climate, the re-

Even man himself, however, though he possesses in nrivalled degree the power of enduring in safety most complete change of climate, scene, and cir- stances, is yet limited, in a certain sense, in his er of migration. The Englishman, for example, endure the fiercest heat of the tropics or the rest cold of Arctic and Antarctic regions. But annot safely attempt to found true colonies in y part of the earth's surface. Our countrymen in a must send their children to be reared in England, ney wish them to grow up strong and vigorous. re can be little doubt that if a thousand men women from this country were to settle in certain s of India (not at any time intermarrying with the ves), the colony would disappear within a couple nturies.

Here we have a second degree of unfitness, accord- to which certain countries would quickly become populated, if supplied with inhabitants from certain r countries. We are taught the same lesson as re, but in a more striking manner. We see differences exist within the confines of our own which render particular countries absolutely habitable by particular races, insomuch that, though individual might survive, the race itself would kly perish. And we see, on the other hand, that e countries are not uninhabited, or even less fully led with living creatures, than seemingly more habitants of one country from visiting others, while t it was possible to learn something of the conditions evailing in other regions, how readily the conclusion ght be reached that some at least of those inacssible regions must be wholly uninhabited, simply cause their physical habitudes appeared unsuited the wants of the only creatures with which the server was familiar. Who would believe, for exple, that men can live, and not only live but thrive d multiply, in the frost-bound regions within the ctic Circle, if travellers had not visited the Esquimaux es, and witnessed the conditions under which they osist? Again, if we knew nothing of India, and ne one pictured to us the intense heat of the Indian n, the strange alternations of weather which replace the Indian the seasonal changes we are familiar h, and all the other circumstances which render pical regions so different from our English home, o could believe that, amidst those seemingly undurable vicissitudes, there are races of men that ive and multiply, even as our people in their temrate zone?[1]

Therefore, in examining the circumstances of other worlds than ours, it will not be sufficient to prove that certain orbs would obviously not be habitable by the races subsisting on the earth, in order to enforce the conclusion that no living creatures subsist at all upon their surface.

---

[1] Perhaps the most striking instance of man's power of living er circumstances seemingly the most unfavourable is to be nd in the fact that though the strongest traveller is affected ously by the rarity of the air at great elevations, yet races of n live and thrive in Potosi, Bogotà, and Quito, and—to use the ds of a modern writer—that bull-fights should be possible at an vation at which Saussure hardly had energy to consult his inuments and where even his guides fainted

Yet another step farther, however. There are regions of the earth where the members of races belonging to other regions *quickly* perish. The air of our own England is death to many creatures. And indeed, there is not a spot in the whole world which would not be fatal in a brief space to many animals and plants belonging to other regions. Yet each spot, though thus fatal to certain races, is inhabited by numbers of others which live and thrive upon its surface.

Here, then, is our third lesson. We are taught by the analogy of our earth that it is not even sufficient to show that a planet would be an abode quickly fatal to all the living creatures subsisting on our globe to prove that it is therefore uninhabited.

But we have yet a stronger argument to touch on. There are regions of our earth to which creatures from other regions cannot be removed without being *immediately* killed. The warm-blooded animal perishes if placed for a brief space under water. The fish perishes if placed for a brief space on the earth.[1] What could be more wonderful to us, were we not familiar with fact, than that there are living creatures within the ths of that ocean beneath whose surface we our- es, and the land creatures we are familiar with, not remain alive many minutes? If fishes could on, how could they believe that creatures can live comfort in that element which is death to them? land and river and sea are alike peopled with ng creatures, each race as well adapted as its ws to the circumstances in which it is placed.

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[1] Perhaps the fact that there are certain kinds of fish which can not only live out of water, but can travel across the dry land, or climb trees, affords an even more striking instance of Nature's power of adapting creatures to the circumstances which surround them

We are taught, then, yet another lesson. We see even though we could prove that every living ture on this earth would at once perish if removed nother orb, yet we cannot thence conclude that orb is uninhabited. On the contrary, the lesson veyed by our earth's analogy leads to the conclusion many worlds may exist, abundantly supplied with ng creatures of many different species, where yet y form of life upon our earth—bird, beast, or fish, ile, insect, or animalcule—would perish in a few nents.[1]

There remains yet a last lesson to be drawn from estrial analogies. On the earth there are regions where no form of life exists or can exist. Within the flaming crater of the volcano, or in the frozen heart of the iceberg, no living creature has its being. Yet even here Nature proves to us that the great end and aim of all her working is to afford scope and room for new forms of life, or to supply the wants of those which already exist. The volcano will die out, and the scene of its activity will one day become the abode of myriads of living creatures who would have perished in a moment in its consuming fires. The iceberg will melt, and its substance will once again be peopled with busy life. But this is little. It is the work of which volcano and iceberg are the signs, which most significantly teaches us what is Nature's real aim. The volcano is the index of those busy subterranean forces which are remodelling the earth's frame, slowly changing the level of the land, making continents of oceans and oceans of continents, preserving and vivifying all things, while all things seem to suffer a gradual destruction. The iceberg, too, has its work in remodelling and fashioning the surface of new continents. It also acts an important part in the formation and maintenance of the system of oceanic circulation on which the welfare of land creatures and water creatures so largely depends. And so of a multitude of other phenomena, which appear at first sight significant rather of the destructive than of the life-preserving character of Nature. The tornado and the thunder-storm, the earthquake and the volcano—nay, even the dreaded returns of plague and pestilence, have each a more werful influence by far towards the preservation than ey have towards the destruction of life.

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[1] I might add to the instances here cited many others which even more striking. We know that in strong acids which ld instantly kill bird, beast, fish, or insect placed within them, e exist and thrive minute creatures, adapted by Nature to the nge conditions in which they are placed. Even in the bowels ne earth and in the very neighbourhood of active volcanoes, we the Volcano-fish existing in such countless thousands that n they are from time to time vomited forth by the erupting ntain their bodies are strewn over enormous regions, and, as

We see, then, that even if we could prove that an in space is so circumstanced that no life could by y possibility exist upon its surface; if it were the ene of a fierce and destructive turmoil, one moment which would suffice to destroy every living creature w existing upon the earth; if its whole mass were ated to a degree a thousandfold more intense than at of the fiercest heat we know of; if its surface were und in a cold compared with which our Arctic frosts uld seem like tropical heat; or even if the most rapid ernation of these extremes took place upon and thin it—even then we could not conclude that it has t been in long-past ages, or will not be in ages yet come, the abode of life.

Lastly, even when we can safely assert of any lestial object that neither now, nor at any past or ture time, could it serve as the abode of living eatures, we are led by terrestrial analogies to the nclusion that it yet supports life in other ways. that these very orbs, of which it seems safest to sert that they are, have ever been, and must ever main uninhabited, speak to us, no less strongly than ose which appear best suited for habitation, of the istence of other worlds than ours.

CHAPTER II.

WHAT WE LEARN FROM THE SUN.

not propose to dwell in this chapter on the views
ı have been, propounded respecting the sun's
ability. It is not merely that I regard those
as too fanciful to find place in a serious con-
ation of the subject I am dealing with, nor that
rogress of recent observation has rendered them
ly untenable, but that, in fact, they do not be-
to what the sun teaches us. I wish to consider
the real evidence which the sun affords respecting
scheme of creation, to dwell upon the purposes
ı he subserves in the economy of the solar system,
hence to deduce a lesson respecting those other
scattered through space which we call the fixed

et us first endeavour to form adequate conceptions
cting the dimensions of the great central luminary
e solar system.

et the reader consider a terrestrial globe three
s in diameter, and search out on that globe the
triangular speck which represents Great Britain.

lives as represented by the minutest pin-mark that ıld possibly be made upon this speck. He will then ve formed some conception, though but an inadequate ., of the enormous dimensions of the earth's globe, mpared with the scene in which his daily life is cast. w, on the same scale, the sun would be represented a globe about twice the height of an ordinary ting-room. A room about twenty-six feet in length, l height, and breadth, would be required to contain e representation of the sun's globe on this scale, ile the globe representing the earth could be placed a moderately large goblet.

Such is the body which sways the motions of the ar system. The largest of his family, the giant piter, though of dimensions which dwarf those of the rth or Venus almost to nothingness, would yet only represented by a thirty-two inch globe, on the scale ich gives to the sun the enormous volume I have oken of. Saturn would have a diameter of about enty-eight inches, his ring measuring about five feet its extreme span. Uranus and Neptune would be tle more than a foot in diameter, and all the minor nets would be less than the three inch earth. It l thus be seen that the sun is a worthy centre of the eat scheme he sways, even when we merely regard dimensions.

The sun outweighs fully 730 times the combined ss of all the planets which circle around him, so at when we regard the energy of his attraction. we

But, after all, the enormous volume and mass of the sun form the least important of his characteristics as the ruling body of the solar system. It is when we contemplate him as the source whence the supplies of heat and light required by our own world and the other planets are plentifully bestowed that we see what is his chief office in the economy of the planetary scheme.

Properly speaking, the physical constitution of the sun only requires to be dealt with in such a work as the present, in so far as it is directly associated with the sun's action upon the worlds around him, or as it may bear on the question of the constitution of those worlds. But the subject is so interesting, and it would indeed be so difficult to draw a line of demarcation between the facts which bear upon the question of other worlds and those which do not, that I may be permitted to enter at some length into a consideration of the solar orb, as modern physical discoveries present it to our contemplation.

The study of solar physics may be said to have commenced with the discovery of the sun-spots, about 267 years ago. These spots were presently found to traverse the solar disc in such a way as to indicate that the sun turns upon an axis once in about twenty-six days. Nor will this rotation appear slow when we remember that it implies a motion of the equatorial parts of the sun's surface at a rate exceeding some seventy times the motion of our swiftest express trains.

Next came the discovery that the solar spots are not
face stains, but deep cavities in the solar substance.
changes of appearance presented by the spots as
y traverse the solar disc, led Dr. Wilson to form this
ory so far back as 1779 ; but, strangely enough, it is
y in comparatively recent times that the hypothesis
been finally established. For even within the last
years a theory was put forward which accounted
sfactorily for most of the changes of appearance
erved in the spots, by supposing them to be due to
r clouds hanging suspended at a considerable eleva-
n above the true photosphere.

Sir William Herschel, reasoning from terrestrial
logies, was led to look on the spot cavities as
rtures through a double layer of clouds. He argued
t were the solar photosphere of any other nature, it
ld be past comprehension that vast openings should
n in it, to remain open for months before they close
again. Whether we consider the enormous rapidity
n which the spots form and with which their figure
nges, or the length of time that many of them remain
ble, we find ourselves alike perplexed, unless we
ume that the solar photosphere resembles a bed of
ds. Through a stratum of terrestrial clouds open-
s may be formed by atmospheric disturbances, but
le undisturbed the clouds will retain any form once
ressed upon them for a length of time correspond-
to the weeks and months during which the solar
ts endure.

varieties of light, the faint penumbra and the dark umbra or nucleus, Herschel saw the necessity of assuming that there are two beds of clouds, the outer self-luminous and constituting the true solar photosphere, the inner reflecting the light received from the outer layer, and so shielding the real surface of the sun from the intense light and heat which it would otherwise receive.

But while recent discoveries have confirmed Sir William Herschel's theory about the solar cloud-envelopes, they have by no means given countenance to his view that the body of the sun may possibly be cool. The darkness of the nucleus of a spot is found, on the contrary, to give proof that in that neighbourhood the sun is hotter, because it parts less readily with its heat. We shall see presently how this is. Meantime let it be noticed in passing that a close scrutiny of large solar spots has revealed the existence of an intensely dark spot in the midst of the umbra. This spot must be regarded as the true nucleus.

The circumstance that the spots appear only on two bands of the sun's globe, corresponding to the sub-tropical zones on our own earth, led the younger Herschel to conclusions as important as those which his father had formed. He reasoned, like his father, from terrestrial analogies. On our own earth the sub-tropical zones are the regions where the great cyclonic storms have their birth, and rage with their chief fury. Here, therefore, we have the analogue of the solar spots, if only we can show reason for believing that causes resembling those which generate the ter- rial cyclone operate upon those regions of the sun re the solar spots make their appearance.

We know that the cyclone is due to the excess of t at the earth's equator. It is true that this ex- of heat is always in operation, whereas cyclones not perpetually raging in sub-tropical climates. inarily, therefore, the excess of heat does not cause adoes. Certain aërial currents are generated, whose orm motion suffices, as a rule, to adjust the condi- s which the excess of heat at the equator would erwise tend to disturb. But when through any se the uniform action of the aërial currents is either rfered with, or is insufficient to maintain equili- m, then cyclonic or whirling motions are generated he disturbed atmosphere, and propagated over a e area of the earth's surface.

Now we recognise the reason of the excess of heat he earth's equator, in the fact that the sun shines e directly upon that part of the earth than on the es which lie in higher latitudes. Can we find any on for suspecting that the sun, which is not heated n without as the earth is, should exhibit a similar uliarity? Sir John Herschel considered that we . If the sun has an atmosphere extending to onsiderable distance from his surface, then there be little doubt that, owing to his rotation upon axis, this atmosphere would assume the figure n oblate spheroid, and would be deepest over the would be retained than at the poles, where the atmosphere is shallowest. Thus that excess of heat at the solar equator which is necessary to complete the analogy between the sun-spots and terrestrial cyclones seems satisfactorily established.

It must be remarked, however, that this reasoning, so far as the excess of heat at the sun's equator is concerned, only removes the difficulty a step. If there were indeed an increased depth of atmosphere over the sun's equator sufficient to retain the requisite excess of heat, then the amount of heat we receive from the sun's equatorial regions ought to be appreciably less than the amount emitted from the remaining portions of the solar surface. This is not found to be the case, so that, either there is no such excess of absorption, or else the solar equator gives out more heat, in other words, is essentially hotter, than the rest of the sun. But this is just the peculiarity of which we want the interpretation.

It may be taken for granted, however, that there is an analogy between the sun-spots and terrestrial cyclonic storms, though as yet we are not very well able to understand its nature.

We come next to one of the most interesting discoveries ever made respecting the sun—the discovery that the spots increase and diminish in frequency in a periodic manner. We owe this discovery to the laborious and systematic observations made by Herr Schwabe, of Dessau. In these pages any account of his work would be out of place. We need only dwell on the result, and upon other discoveries which ve been made by observers who have taken up the ne work.

Schwabe found that in the course of about eleven ars the solar spots pass through a complete cycle changes. They become gradually more and more merous up to a certain maximum, and then as adually diminish. At length the sun's face becomes t only clear of spots, but a certain well-marked rkening around the border of his disc disappears ogether for a brief season. At this time the sun esents a perfectly uniform disc. Then gradually the ots return, become more and more numerous, and so e cycle of changes is run through again.

The astronomers who have watched the sun from e Kew observatory have found that the process of ange by which the spots sweep in a sort of 'wave increase' over the solar disc is marked by several inor variations. As the surface of a great sea-wave ll be traversed by small ripples, so the gradual in- ease and diminution in the number of the solar spots characterised by minor gradations of change, which e sufficiently well marked to be distinctly cognisable.

There seems every reason for believing that the riodic changes thus noticed are due to the influence ' the planets upon the solar photosphere, though in hat way that influence is exerted is not at present erfectly clear. Some have thought that the mere traction of the planets tends to produce tides of height of a tide so produced varies as the cube or third power of the distance, it has been thought that a planet when in perihelion would generate a much larger solar tide than when in aphelion. So that, as Jupiter has a period nearly equal to the sun-spot period, it has been supposed that the attractions of this planet are sufficient to account for the great spot-period. Venus, Mercury, the Earth, and Saturn have, in a similar manner, been rendered accountable for the shorter and less distinctly marked periods.

Without denying that the planets may be, and probably are, the bodies to whose influence the solar-spot periods are to be ascribed, I yet venture to express very strong doubts whether the action of Jupiter is so much greater in perihelion than in aphelion as to account for the fact that, whereas at one season the face of the sun shows many spots, at another it is wholly free from them.

However, we are not at present concerned so much with the explanation of facts as with the facts themselves. We have to consider rather what the sun is, and what he does for the solar system, than why these things are so.

Let us note, before passing to other circumstances of interest connected with the sun, that the variable condition of his photosphere must cause him to change in brilliancy as seen from vast distances. If Herr Schwabe, for instance, instead of observing the sun's spots from his watch tower at Dessau, could have removed himself to a distance so enormous that the sun's disc would have been reduced, even in the most powerful telescope, to a mere point of light, there can be no doubt that the only effect which he would have been able to perceive would have been a gradual increase and diminution of brightness, having a period of about eleven years.

Our sun, therefore, if viewed from the neighbourhood of any of the stars, whence undoubtedly he would simply appear as one among many fixed stars, would be a 'variable,' having a period of about eleven years, and a very limited range of variation. Further, if an observer, viewing the sun from so enormous a distance, had the means of very accurately measuring its light, he would undoubtedly discover that while the chief variation of the sun takes place in a period of about eleven years, its light is subjected to minor variations, having shorter periods.

The discovery that the periodic changes of the sun's appearance are associated with the periodic changes in the character of the earth's magnetism is the next that we have to consider.

It had long been noticed that during the course of a single day the magnetic needle exhibits a minute change of direction, taking place in an oscillatory manner. And when the character of this vibration came to be carefully examined, it was found to correspond to a sort of effort on the needle's part to turn towards the sun. For example, when the sun is on the magnetic meridian, the needle has its mean position. This happens twice in the day, once when the sun is above the horizon, and once when he is below it. Again, when the sun is midway between these two positions—which also happens twice in the day—the needle has its mean position, because the northern and the southern ends make equal efforts, so to speak, to direct themselves towards the sun. Four times in the day, then, the needle has its mean position, or is directed towards the magnetic meridian. But when the sun is not in one of the four positions considered, that end of the needle which is nearest to him is slightly turned away from its mean position, towards him. The change of position is very minute, and only the exact methods of observation made use of in the present age would have sufficed to reveal it. There it is, however, and this minute and seemingly unimportant peculiarity has been found to be full of meaning.

Had science merely measured this minute variation, the work would have given striking evidence of the exact spirit in which men of our day deal with natural phenomena. But science was to do much more. The variations of this minute variation were to be inquired into; their period was to be searched for; the laws by which they were regulated, and by which their period might perhaps itself be rendered variable, were to be examined; and finally their relation to other natural laws was to be sought after. That science should set herself to an inquiry so delicate and so difficult, in a spirit so exacting, was nothing unusual. It is thus that all the great discoveries of our age have been effected. But it is well that the reader should recognise the

eful scrutiny to which natural phenomena have
n subjected before the great laws we have to con-
r were made known. It is thought by many, who
e not been at the pains to examine what science is
lly doing in our day, that the wonders she presents
nen's contemplation, the startling revelations which
being made from day to day, are merely dreams
l fancies, which replace indeed the dreams and
cies of old times, but have no worthier claims on
belief. Those who carefully examine the history of
nce will be forced to adopt a very different opinion.

The minute vibrations of the magnetic needle, thus
efully watched—day after day, month after month,
r after year—were found to exhibit a yet more
nute oscillatory change. They waxed and waned
hin narrow limits of variation, but yet in a manner
re was no mistaking. The period of this oscillatory
nge was not to be determined, however, by the ob-
vations of a few years.[1] Between the time when
diurnal vibration was least until it had reached its
atest extent, and thence returned to its first value,
less than eleven years elapsed, and a much longer
e passed before the periodic character of the change
satisfactorily determined.

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[1] The reader must not understand that the account here given
ents in any sense even a general view of the labours of those
have studied the earth's magnetism. I touch only on those
ts by which the association between the earth's magnetism and
physical condition of the sun are most clearly indicated; be-

The reader will at once see what these observations tend to. The sun-spots vary in frequency within a period of eleven years, and the magnetic diurnal observations vary within a period of the same duration. It might seem fanciful to associate the two periodic series of changes together, and doubtless when the idea first occurred to Sabine, it was not with any great expectation of finding it confirmed, that he examined the evidence bearing on the point. Judging from known facts, we may see reasons for such an expectation in the correspondence of the needle's diurnal vibration, with the sun's apparent motion, and also in the law which associates the annual variations of the magnet's power with the sun's distance. But undoubtedly when the idea occurred to Sabine, it was an exceedingly bold one, and the ridicule with which the first announcement of the supposed law was received, even in scientific circles, suffices to show how unexpected that relation was which is now so thoroughly established. For a careful comparison between the two periods has demonstrated that they agree most perfectly, not merely in length, but maximum for maximum, and minimum for minimum. When the sun-spots are most numerous, then the daily vibration of the magnet is most extensive; while when the sun's face is clear of spots, the needle vibrates over its smallest diurnal arc.

Then the intensity of the magnetic action has been found to depend upon solar influences. The vibrations by which the needle indicates the progress of

se strange disturbances of the terrestrial magnetism
ch are known as magnetic storms, have been found
merely to be most frequent when the sun's face
nost spotted, but to occur simultaneously with the
earance of signs of disturbance in the solar photo-
ere. For instance, during the autumn of 1859
eminent solar observer, Carrington, noticed the
arition of a bright spot upon the sun's surface.
e light of this spot was so intense that he imagined
screen which shaded the plate employed to receive
solar image had been broken. By a fortunate
ncidence another observer, Mr. Hodgson, hap-
ed to be watching the sun at the same instant,
d witnessed the same remarkable appearance. Now
vas found that the self-registering magnetic instru-
nts of the Kew observatory had been sharply dis-
bed at the instant when the bright spot was seen.
d afterwards it was learned that the phenomena
ch indicate the progress of a magnetic storm had
n observed in many places. Telegraphic commu-
ation was interrupted, and at a station in Norway
telegraphic apparatus was set on fire; auroras
eared both in the northern and southern hemi-
eres during the night which followed; and the
ole frame of the earth seemed to thrill responsively
the disturbance which had affected the great central
inary of the solar system.

The reader will now see why I have discussed
ations which hitherto he may perhaps have thought

e is a bond of sympathy between our earth and the
that no disturbance can affect the solar photo-
re without affecting our earth to a greater or less
ee. But if our earth, then also the other planets.
cury and Venus, so much nearer the sun than we
surely respond even more swiftly and more dis-
ly to the solar magnetic influences. But beyond
earth, and beyond the orbit of moonless Mars, the
netic impulses speed with the velocity of light.
vast globe of Jupiter is thrilled from pole to pole
ne magnetic wave rolls in upon it; then Saturn
the shock, and then the vast distances beyond
h lie Uranus and Neptune are swept by the ever-
ning yet ever-widening disturbance-wave. Who
say what outer planets it then seeks? or who,
ing back upon the course over which it has tra-
ed, shall say that planets alone have felt its effects?
eoric and cometic systems have been visited by the
t magnetic wave, and upon the dispersed members
ne one and the subtle structure of the other effects
more important may have been produced than
e striking phenomena which characterise the pro-
s of terrestrial or planetary magnetic storms.

When we remember that what is true of a rela-
y great solar disturbance, such as the one wit-
ed by Messrs. Carrington and Hodgson, is true
(however different in degree) of the magnetic in-

only sways them by the vast attraction of his vity, not only illumines them, not only warms them, he pours forth on all his subtle yet powerful mag- ic influences. A new analogy between the members the solar system is thus introduced.

And now we pass on to other discoveries, bearing once and with equal force upon the relations be- een the various members of the solar system and on the position which that system occupies in the iverse.

Hitherto we have been considering the teachings of e telescope; we have now to consider what we have rned by means of an instrument of yet higher vers. As I shall have to refer very frequently, oughout this volume, to the teachings of the spec- scope, it will be well that I should briefly describe at it is that this instrument really effects. Were I ply to state the results of its use, without describing real character, many of my readers would be dis- ed to believe that astronomers are as credulous as reality they are exacting and scrupulous, where new ts and observations are in question.

The real end and aim of the telescope, as applied the astronomer to the examination of the celestial ects, is to gather together the light which streams m each luminous point throughout space. We may gard the space which surrounds us on every side as ocean without bounds or limits, an ocean across ich there are ever sweeping waves of light either

ghout space, or else reflected from their surfaces.
forms of wave also speed across those limitless
s in all directions; but the light-waves are those
at present concern us. Our earth is as a minute
placed within the ocean of space, and to the
; of this tiny isle the light-waves bear their mes-
rom the orbs which lie like other isles amid the
nless depths around us. With the telescope the
omer gathers together portions of light-waves
else would have travelled in diverging directions.
us intensifying their action, he enables the eye
ome cognisant of their true nature. Precisely as
arrow channels around our shores cause the tidal
which sweeps across the open ocean in almost
sible undulations, to rise and fall through a wide
of variation, so the telescope renders sensible
xistence of light-waves which would escape the
of the unaided eye.

ne telescope, then, is essentially a *light-gatherer*.
ne spectroscope is used for another purpose. It
be called the *light-sifter*. It is applied by the
omer to analyse the light which comes to him
beyond the ocean of space, and so to enable him
rn the character of the orbs from which that
proceeds.

ne principle of the instrument is simple, though
ppliances by which its full powers can alone be

Different portions of the ray are differently bent, so hat when they emerge from the prism they no longer ravel side by side as before. The violet part of the ight is bent most, the red least; the various colours rom violet through blue, green, and yellow, to red, eing bent gradually less and less.

The prism then *sorts*, or *sifts*, the light-waves.

But we want the means of sifting the light-waves more thoroughly. The reader must bear with me while I describe, as exactly as possible in the brief pace available to me, the way in which the first rough work of the prism has been modified into the delicate nd significant work of the spectroscope. It is well worth while to form clear views on this point, because o many of the wonders of modern science are assoiated with spectroscopic analysis.

If, through a small round hole in a shutter, light s admitted into a darkened room, and a prism be laced with its refracting angle downwards and horiontal, a vertical spectrum, having its violet end uppermost, will be formed on a screen suitably placed to eceive it.

But now let us consider what this spectrum really s. If we take the light-waves corresponding to any articular colour, we know from optical considerations hat these waves emerge from the prism in a pencil xactly resembling in shape the pencil of white light which falls on the prism. They therefore form a small ircular or oval image on their own proper part of the

titude of overlapping images, varying in colour
violet to red. It thus appears as a rainbow-
d streak, presenting every gradation of colour
een the utmost limits of visibility at the violet
ed extremities.

' we had a square aperture to admit the light, we
d get a similar result. If the aperture were
g, there would still be overlapping images ; but if
ngth of the oblong were horizontal, then, since
image would also be a horizontally-placed oblong,
verlapping would be less than when the images
square. Suppose we diminish the overlapping as
as possible; in other words, suppose we make
blong slit as narrow as possible. Then, unless
were in reality an infinite number of images dis-
ted all along the spectrum from top to bottom, the
es might be so narrowed as not to overlap; in
a case, of course, there would be horizontal dark
s or gaps in our spectrum. Or again, if we
in finding gaps of this sort by simply narrowing
perture, we might lengthen the spectrum by in-
ing the refracting angle of the prism, or by using
al prisms, and so on.

he first great discovery in solar physics, by means
e analysis of the prism (though the discovery had
meaning at the time), consisted in the recogni-
of the fact that by means of such devices as the

trum from violet to red, do *not* travel to us from the great central luminary of our system. Remembering that the effect we call colour is due to the length of the light-waves, the effect of red corresponding to light-waves of the greatest length, while the effect of violet corresponds to the shortest light-waves, we see that in effect the sun sends forth to the worlds which circle around him light-waves of many different lengths, but not of all lengths. Of so complex and interesting a nature is ordinary daylight.

But spectroscopists sought to interpret these dark lines in the solar spectrum, and it was in carrying out this inquiry—which even to themselves seemed almost hopeless, and to many would appear an utter waste of time—that they lighted upon the noblest method of research yet revealed to man.

They examined the spectra of the light from incandescent substances (white-hot metals and the like), and found that in these spectra there are no dark lines.

They examined the spectra of the light from the stars, and found that these spectra are crossed by dark lines resembling those in the solar spectrum, but differently arranged.

They tried the spectra of glowing vapours, and they obtained a perplexing result. Instead of a number of dark lines across a rainbow-tinted streak, they found bright lines of various colour. Some gases would give a few such lines, others many, some only one or two.

Then they tried the spectrum of the electric spark, and they found here also a series of bright lines, but not always the same series. The spectrum varied according to the substances between which the spark was taken and the medium through which it passed.

Lastly, they found that the light from an incandescent solid or liquid, when shining through various vapours, no longer gives a spectrum without dark lines, but that the dark lines which then appear vary in position, according to the nature of the vapour through which the light has passed.

Here were a number of strange facts, seemingly too discordant and too perplexing to admit of being interpreted. Yet one discovery only was wanting to bring them all into unison.

In 1859 Kirchhoff, while engaged in observing the solar spectrum, lighted on the discovery that a certain double dark line, which had already been found to correspond exactly in position with the double bright line forming the spectrum of the glowing vapour of sodium, was intensified when the light of the sun was allowed to pass through that vapour. This at once suggested the idea that the presence of this dark line (or, rather, pair of dark lines) in the spectrum of the sun is due to the existence of the vapour of sodium in the solar atmosphere, and that this vapour has the power of absorbing the same order of light-waves as it emits. It would of course follow from this that the other dark lines in the solar spectrum are due to the presence of other absorbent vapours in its atmosphere, and that the identity of these would admit of being established in the same way, supposing this general law to hold at a vapour emits the same light-waves that it is pable of absorbing.

Kirchhoff was soon able to confirm his views by a riety of experiments. The general principles to hich his researches led—in other words, the principles hich form the basis of spectrum analysis—are as llow:

1. An incandescent solid or liquid gives a connuous spectrum.

2. A glowing vapour gives a spectrum of bright nes, each vapour having its own set of lines, so that om the appearance of a bright-line spectrum one can ll the nature of the vapour or vapours whose light rms the spectrum.

3. An incandescent solid or liquid shining through osorbent vapours gives a rainbow-tinted spectrum rossed by dark lines, these dark lines having the same osition as the bright lines belonging to the spectra of he vapours; so that, from the arrangement of the ark lines in such a spectrum, one can tell the nature the vapour or vapours which surround the source of ght.[1]

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[1] To these may be added the following laws:

4. Light reflected from any opaque body gives the same specum as it would have given before reflection.

5. But if the opaque body be surrounded by vapours, the dark nes corresponding to these vapours make their appearance in the ectrum with a distinctness proportioned to the extent to which e light has penetrated those vapours before being reflected to us.

6. If the reflecting body be itself luminous, the spectrum benging to it is superadded to the spectrum belonging to the reected light.

The application of the new method of research to the study of the solar spectrum quickly led to a number of most interesting discoveries. It was found that besides sodium the sun's atmosphere contains the vapours of iron, calcium, magnesium, chromium, and other metals. The dark lines corresponding to these elements appear unmistakably in the solar spectrum. There are other metals—such as copper and zinc—which seem to exist in the sun, though some of the corresponding dark lines have not yet been recognised. As yet it has not been proved that gold, silver, mercury, tin, lead, arsenic, antimony, or aluminium exist in the sun—though we can by no means conclude, nor indeed is it at all probable, that they are absent from his substance. The dark lines belonging to hydrogen are very well marked indeed in the solar spectrum, and, as we shall see presently, the study of these lines has afforded most interesting information respecting the physical constitution of the sun.

Now, we notice at once how importantly these researches into the sun's structure bear upon the sub-

may cause bright lines or dark lines to appear in the spectrum, according as they are more or less heated, or they may emit just so much light as to make up for what they absorb, in which case there will remain no trace of their presence.

8. The electric spark presents a bright-line spectrum, compounded of the spectra belonging to the vapours of those substances between which, and of those through which, the discharge takes place. According to the nature of these vapours and of the discharge itself, the relative intensity of the component parts of the spectrum will be variable.

Lastly, the appearance of the spectrum belonging to any element will vary according to the circumstances of pressure and temperature under which the element may emit light.

ject of this treatise. It would be indeed interesting to consider the actual condition of the central orb of the planetary scheme, to picture in imagination the metallic oceans which exist upon his surface, the continual evaporation from those oceans, the formation of metallic clouds, and the downpour of metallic showers upon the surface of the sun. But apart from such considerations, and viewing Kirchhoff's discoveries simply in their relation to the subject of other worlds, we have enough to occupy our attention.

If it could have been shown that, in all probability, the substance of the sun consists of materials wholly different from those which exist in this earth, the conclusion obviously to be drawn from such a discovery would be that the other planets also are differently constituted. We could not find any just reason for believing that in Jupiter or Mars there exist the elements with which we are acquainted, when we found that even the central orb of the planetary system exhibits no such feature of resemblance to the earth. But now that we know quite certainly that the familiar elements iron, sodium, and calcium exist in the sun's substance, while we are led to believe, with almost perfect assurance, that all the elements we are acquainted with also exist there, we see at once that in all probability the other planets are constituted in the same way. There may of course be special differences. In one planet the proportionate distribution of the elements may differ, and even differ very

But the general conclusion remains, that the planets are formed of the elements which have so long been known as terrestrial; for we cannot recognise any reason for believing that our earth alone, of all the orbs which circle around the sun, resembles that great central orb in general constitution.[1]

Now, we have in this general law a means of passing beyond the bounds of the solar system, and forming no indistinct conceptions as to the existence and character of worlds circling around other suns. For it will be seen in the chapter on the stars that these orbs, like our sun, contain in their substance many of the so-called terrestrial elements, while it may not unsafely be asserted that all or nearly all those elements, and few or no elements unknown to us, exist in the substance of every single star that shines upon us from the celestial concave. Hence we conclude that around those suns also there circle orbs constituted like themselves, and therefore containing the elements with which we are familiar. And the mind is immediately led to speculate on the uses which those elements are intended to subserve. If iron, for example, is present in some noble orb circling around Sirius, we speculate not unreasonably respecting the existence on that orb —either now, or in the past, or at some future time— of being capable of applying that metal to the useful purposes which man makes it subserve. The imagition suggests immediately the existence of arts and iences, trades and manufactures, on that distant orld. We know how intimately the use of iron has en associated with the progress of human civilisa- on, and though we must ever remain in ignorance the actual condition of intelligent beings in other orlds, we are yet led, by the mere presence of an ement which is so closely related to the wants man, to believe, with a new confidence, that for ch beings those worlds must in truth have been hioned.

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[1] It will be seen, in the chapter on 'Meteors and Comets,' that this conclusion has a most important bearing on the views we are to form respecting the original formation of the planetary scheme.

I would fain dwell longer on the thoughts suggested the researches of Kirchhoff. Gladly, too, would I ter at length on an account of those interesting dis- veries which have been made in connection with cent total eclipses of the sun. The requirements space, however, and some doubt as to the direct aring of the last-named discoveries on the subject I ve in hand, warn me to forbear. One point, how- er, remains, which is too intimately connected with subject to be passed over.

I refer to the sun's corona.

It has been proved that the solar prominences con- t of glowing vapours, hydrogen being their chief nstituent. It has been found also, by comparing servations of the prominence-spectra with elaborate searches into the peculiarities presented by the spec- um of hydrogen at different pressures, that even in e very neighbourhood of the solar photosphere these indicate that the limits of the sun's vaporous envelope cannot lie very far (relatively) from the outer solar cloud-layer.

Now the solar corona has been seen, during total eclipses of the sun, to extend to a distance at least equal to the sun's diameter from the eclipsed orb. So that, assuming the corona to be a solar atmosphere, it would have a depth of about 850,000 miles, and being also drawn towards the sun by his enormous attractive energy (exceeding more than twenty-seven times that of the earth), it could not fail to exert a pressure on his surface exceeding many thousand-fold that of our air upon the earth. In fact, such an atmosphere, let its outermost layers be as rare as we can conceive, would yet have its lower layers absolutely liquefied, if not solidified, by the enormous pressure to which they would be subjected. We cannot, then, believe this corona to be a solar atmosphere.

Yet it is quite impossible to dissociate the corona from the sun. Until 1872 some attempted to do this, and not only so, but to make of the zodiacal light a terrestrial phenomenon. But they had overlooked considerations which oppose themselves irresistibly to such a conclusion; and since the observation of the solar eclipse of December 1871, astronomers are of one accord in regarding the corona as appertaining to the sun.

But the spectroscope has given certain very perplexing evidence respecting the light of the corona, and it remains that we should endeavour to see how at evidence bears on the interesting problem which e corona presents to our consideration.

During the total eclipse of August 1869 the Ame-can observers found that the spectrum of the corona continuous, but crossed by certain bright lines. If e accept the absence of dark lines as established by e evidence (which is doubtful), this result seems at rst sight very difficult to explain. Referring to the rinciples of spectroscopic analysis stated at pp. 38, 39, will be seen that we should be led to infer that the rona consists of incandescent matter surrounded by rtain glowing gases. It is difficult to suppose that is is the real explanation of the phenomenon.

Now, remembering that we have two established cts for our guidance—(i) the fact that the outer rona cannot be a solar atmosphere, and (ii) the fact at it must be a solar appendage—I think a way may e found towards a satisfactory explanation.

Let it be premised that the bright lines of the onal spectrum correspond in position, though not in rightness, to those seen in the spectrum of the aurora, nd that the same lines are seen in the spectrum of the diacal light, and in that of the phosphorescent light casionally seen over the heavens at night.

Since we have every reason to believe that the light f the aurora is due to electrical discharges taking lace in the upper regions of the air, we are invited to e belief that the coronal light may be due to similar ischarges taking place between the particles (of what-

Now, though the appearance of an aurora is due to some special terrestrial action (however excited), yet the material substances between which the discharges take place must be assumed to be at all times present in the upper regions of air. In all probability, they are the particles of those meteors which the earth is continually encountering. And since we know that meteor systems must be aggregated in far greater numbers near the sun than near the earth, we may regard the coronal light as due to electrical discharges excited by the sun's action, and taking place between the members of such systems. Besides this light, however, there must necessarily be a large proportion of light reflected from these meteoric bodies. In this way the peculiar character of the coronal spectrum may be readily accounted for. We know from the auroral spectrum that the principal bright lines due to the electrical discharges would be precisely where we see bright lines in the coronal spectrum. But, besides these, there would be fainter bright lines, corresponding to the various elements which exist in the meteoric masses. These elements, we know, are the same as those in the substance of the sun. Thus, the bright lines would correspond in position with the dark lines of the solar spectrum. Hence, as light reflected by the meteors would give the ordinary solar spectrum, there would result from the combination a continuous spectrum, on which the bright lines first mentioned would be seen, as during the American eclipse.

What the polariscope has told us respecting the rona is in accordance with this view.

In the same way the quality of the zodiacal light mits of being perfectly accounted for, without rerting to the hypothesis that this phenomenon is a restrial one.

The explanation thus put forward has at least the vantage of being founded on well-established relans. We know that the auroral light is associated h the earth's magnetism, and that meteoric bodies e continually falling upon the earth's atmosphere. e know also that the sun exerts magnetic influences housand-fold more intense than those of the earth, l that in his neighbourhood there must be many llion times more meteoric systems.

But we have other and independent reasons, which ıst not be overlooked, for considering the corona to of some such nature as I have suggested.

Leverrier has shown that there probably exists in e neighbourhood of the sun a family of bodies whose ited mass suffices appreciably to affect the motions the planet Mercury. It would not be safe to neglect nsiderations thus vouched for.

Now, whatever opinion we form as to the exact aracter of the system of bodies pointed to by verrier's researches — whether we suppose that stem to form a zone around the sun, or that (as I lieve) the system is merely due to the aggregation meteoric perihelia in the sun's neighbourhood — we

e quite certain that during a total solar eclipse
stem would become visible.

the eclipse of December 1871 striking evi-
was obtained respecting the corona. For Janssen
le to perceive the solar dark lines in the spec-
f the corona—proof unmistakable that a portion
coronal light is reflected sunlight. It had been
culty in the meteoric theory that these solar
nad not been detected in the faint continuous
um of the corona. The meteoric theory, that is,
eory that a portion of the coronal light is due to
eflecting meteors round the sun, accorded with
e known phenomena of the corona except this
peculiarity, that (as was supposed) the spectrum
d no dark lines. Now that the dark lines have
seen, all doubt seems finally removed. As
n said in the letter containing the discovery, 'the
pheric theory is disposed of (*tranchée*), and we
recognise in the corona a circumsolar phenomenon
ning effects of radiation, absorption, and reflection
t,' which it must be the business of future eclipse
ers to analyse in detail.

ring the eclipse of July 1878 the corona was
to extend to at least seven or eight millions of
from the body of the sun.

will be seen, in the chapter on 'Meteors and
s,' how important a bearing the meteor theory

artly for this reason that I have here briefly considered ne matter; but there is another and a most important lation in which these views must be regarded.

We know that the sun is the sole source whence ght and heat are plentifully supplied to the worlds hich circle around him. The question immediately uggests itself—Whence does the sun derive those mazing stores of force from whence he is continually upplying his dependent worlds? We know that, ere the sun a mass of burning matter, he would be onsumed in a few thousand years. We know that, ere he simply a heated body, radiating light and heat ontinually into space, he would in like manner have xhausted all his energies in a few thousand years— mere day in the history of his system. Whence, en, comes the enormous supply of force which he as afforded for millions on millions of years, and which e will doubtless continue to afford for at least as long a me as the worlds which circle around him have need of —in other words, for countless ages yet to come?

Now there are two ways in which the solar energies might be mantained. The mere contraction of ne solar substance, Helmholtz tells us, would suffice supply such enormous quantities of heat, that if the eat actually given out by the sun were due to this use alone, there would not, in many thousands of ears, be any perceptible diminution of the sun's ameter. Secondly, the continual downfall of meteors upon the sun would cause an emission of heat.

would not be rendered perceptible in thousands of years, either by any change in his apparent size or by changes in the motions of his family of worlds, yet the supply of heat obtainable in this way can be but small compared with the sun's emission of heat. This follows from the limits between which Leverrier has shown that the total mass of the meteors of our system must certainly lie.[1]

It seems far from unlikely that both these processes are in operation at the same time. Certainly the latter is, for we know, from the motions of the meteoric bodies which reach the earth, that myriads of these bodies must continually fall upon the sun. If the corona and zodiacal light are really due to the existence of flights of meteoric systems circling around the sun, or to the existence in his neighbourhood of the perihelia of many meteoric systems, then there must be a supply of light and heat from this source, though not nearly sufficient to account for the solar emission.

It is worthy of notice, however, that the association between meteors and comets has some bearing on this question. We know that the most remarkable characteristic of comets is the enormous diffusion of their substance. Now in this diffusion there resides an enormous fund of force. The contraction of a large comet to dimensions corresponding to a very moderate mean density would be accompanied by the emission of much heat. The question is worth inquiring into, whether we can indeed assume that all meteors which reach our atmosphere are solid bodies. Some may be of cometic diffusion. But, be this as it may, it is certain that a large portion of the substance of every comet is in a singularly diffused state. Since the meteoric systems circling in countless millions round the sun are, in all probability, associated in the most intimate manner with comets, we may recognise in this diffusion, as well as in the mere downfall of meteors, the source of an enormous supply of light and heat.

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[1] Undue stress has been laid upon the probable change in the length of the year, owing to the downfall of meteors upon the sun's mass. It is forgotten that the crowded meteors forming the solar corona are *already* within the earth's orbit, and therefore already produce their full effect on the length of the year. The subsidence of all these bodies at once upon the sun would not affect the length of the year, though it would lead to *certain* modifications in the secular perturbations of the earth's orbit in figure and position.

Lastly, turning from our sun to the other suns, which shine in uncounted myriads throughout space, we see the same processes at work upon them all. Each star-sun has its coronal and its zodiacal discs, formed by meteoric and cometic systems; for otherwise each would quickly cease to be a sun. Each star-sun emits, no doubt, the same magnetic influences which give to the zodiacal light and to the solar corona their peculiar characteristics. Thus the worlds which circle round those orbs may resemble our own in all those relations which we refer to terrestrial magnetism, as well as in the circumstance that on them also there must be, as on our own earth, a continual downfall of minute meteors. In those worlds, perchance, the mag-

ompass directs the traveller over desert wastes
kless oceans; in their skies, the aurora displays
liant streamers; while, amid the constellations
deck their heavens, meteors sweep suddenly into
nd comets extend their vast length athwart the
l vault.

CHAPTER III.

THE INFERIOR PLANETS.

In considering the habitability of various portions of the solar system, we have to draw a marked distinction between the planets which travel within the orbit of the earth and those which lie beyond its range. So far, indeed, as our belief in these orbs being inhabited is concerned, we may apply the same processes of reasoning to one set of planets as to the other. Until it has been demonstrated that no form of life can exist upon a planet, the presumption must be that the planet is inhabited. But it is impossible to contemplate the various members of our solar system without being led to consider their physical habitudes rather with relation to the wants of such creatures as exist upon our own earth, than merely with reference to the existence of life of some sort upon their surface. Viewing Venus and Mercury in this way, we have a different set of relations to deal with than we find among the outer planets. We are struck at once with the marked effects which seem associable with their comparative proximity to the sun's orb. This feature and the shortness of their period of revolution—that is, of their year—are the characteristic peculiarities we have to deal with.

I would willingly pay some attention here to the story of Vulcan, the planet which has been supposed to circle yet more closely than Mercury around the centre of our system, were it not that I regard the existence of this planet as utterly unlikely.

Mercury circles around the sun in the brief period of eighty-eight days, or rather less than three of our months. So that, if the planet has seasons, these must be severally about three weeks long. His distance from the sun varies between somewhat wide limits, owing to the eccentricity of his orbit. When he is nearest to the sun, he receives ten and a half times more light and heat from that luminary than we do; but when he removes to his greatest distance, the light and heat he receives are reduced by more than one-half. Even then, however, the sun blazes in the skies of Mercury with a disc four and a half times larger than that which he presents to the observer on earth.

Undoubtedly these peculiarities, the shortness of the Mercurial year, and the immense amount of light and heat poured by the sun upon the planet, are circumstances which do not encourage, at first sight, the belief that any creatures can subsist upon this planet resembling those with which we are familiar. We see at once that all forms of vegetation in Mercury must differ in a very striking manner from those which exist upon the earth, because their structure has to be adapted to much more rapid changes of temperature.

nd the existence of a totally distinct flora suggests once the belief that animal life on Mercury must be ry different from what we see around us.

Let us, however, proceed a few steps farther.

It has been found that Mercury rotates upon his is, and if we may put faith in the observations of hröter, the Mercurial day is only a few minutes nger than our own. But though the fact of the anet's rotation has been observed, it has not been und possible to determine in what position the axis rotation lies. It has been said that the planet's uator is much more inclined than the earth's to the ane in which the planet travels; but little reliance n be placed on the evidence which has been adduced favour of this view.

We are thus left altogether in doubt as to the ture of the Mercurial seasons. That the planet has asons of some sort we are certain, because even if e axis were so placed that perpetual spring reigned on the planet—I mean, that the days and nights re at all times and in all places equal—yet his ying distance from the sun would give changes of mperature quite as marked as those which charac- ise our seasons in England, and very much more rked than those known in tropical regions. Of urse, if this is the actual arrangement, there are dif- ent climates in different parts of the planet. Near poles the sun, though visible for half the Mercurial y, attains yet but a low elevation above the horizon;

circles. At the equator the sun passes day after day to the zenith, and pours down upon the planet an amount of light and heat far exceeding the light and heat of our tropical climates. A sun immediately overhead, and showing a diameter varying from more than twice to more than three times that of our sun, must be a noble and may be a terrible phenomenon in the skies of Mercury.

There is yet another arrangement by which, to a portion of the planet, at any rate, the Mercurial seasons might be tempered. If his axis is so placed that what would be the winter season were his orbit not eccentric takes place, for one hemisphere, when the planet is nearest to the sun, then undoubtedly it may very well happen (the inclination of his axis being suitably adjusted) that this so-called winter season is the warmest part of the year for that hemisphere. In this case there would be the least possible violence in the succession of the Mercurial seasons for that hemisphere. But in the other hemisphere the seasonal changes would be correspondingly intensified.

In either of these cases, it is readily conceivable that even forms of life resembling those we are acquainted with on earth might exist on Mercury, and this without any special provision for tempering the great heat and light of the sun. Those regions which correspond to our temperate and tropical zones would indeed scarcely be habitable; but the polar regions of the planet would not form a disagreeable abode.

If, however, the equator of the planet is very much inclined to the plane in which Mercury travels, it cannot be doubted that no form of life known upon earth can possibly exist upon Mercury, *without* some special arrangements for tempering the seasonal changes. This will appear when we come to deal with the effect of the great inclination which some astronomers have ascribed to the equator of Venus; and therefore we need not consider the relation with regard to Mercury, respecting whose axial inclination no trustworthy information has hitherto been obtained.

It remains for us to consider what sort of provision may have been made to temper the great heat poured by the sun upon Mercury.

The climate of a planet, considered generally, is largely influenced by the nature of the planet's atmosphere. We have very clear evidence on this point, in the effects which we notice on our own earth. If we ascend to the summit of a lofty mountain, we find the air much colder than at its base. In India, though the full heat of a tropical sun is poured day after day upon the snowy summits of the Himalayas, yet the air continues colder than in the bitterest midwinter weather experienced by us in England. Not that the solar rays have no power. The heat is, in reality, even greater than on the plains, because it has not been intercepted by vapour-laden air. But the air itself is not heated. Owing to its extreme rarity and dryness, it neither impedes the passage of the sun's heat to the earth, nor prevents the return of that heat from the earth by radiation or reflection; and this very fact, that it does not impede the passage of heat, means nothing else than that the air does not become heated.[1]

We have, then, so far as a rare atmosphere is concerned, two points to dwell upon—the readiness with which such an atmosphere permits the sun's heat to reach the surface of a planet, and the readiness with which it permits the planet's heat to pass away into space. Now we might feel doubtful which of these two effects was chiefly to be regarded, were it not that on our own earth we have experience of the effects of a very rare atmosphere. We know that the climate of very elevated regions is relatively much cooler than that of places on the plain. Thus we learn that the direct heating powers of the sun are not so much to be considered, in judging of the climate of any region, as the quality of the atmosphere.

Yet we must not deceive ourselves by inferring that mere rarity of atmosphere can compensate fully for an increased intensity of solar heat. It is not true that the climate of a place on the slopes of the Andes or the Himalayas corresponds to that of a region on the plain which has an atmosphere equally warm. The circumstances are, in fact, wholly different. On the plain there is, it is true, the same amount of heat in the case supposed; but the air is denser and more moisture-laden: the nights are warmer because the skies are less clear and the heat escaping from the earth is intercepted by clouds or by the transparent aqueous vapour in the air; and, lastly, there is not so great a contrast between the warmth of the air and the direct heat of the solar rays.

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[1] The following passage, quoted by Prof. Tyndall from Hooker's 'Himalayan Journals,' illustrates the peculiarities referred to above: 'At 10,000 feet, in December, at 9 A.M., I saw the mercury mount to 132°, while the temperature of shaded snow hardly was 22°. At 13,100 feet, in January, at 9 A.M., it has stood at 98°, with a difference of 68·2°, and at 10 A.M., at 114°, with a difference of 81·4°, whilst the radiating thermometer on the snow had fallen at sunrise to 0·7°.' Such observations as these are well worth studying. It is interesting to consider that at the summit of the highest peaks of the Himalayas the mid-day heat due to the sun must sometimes be near if not above the boiling point corresponding to those places, since water would boil on Mount Everest at a temperature of little more than 160°.

If the atmosphere of Mercury, therefore, be excessively rare, as some have supposed, so as to afford an Alpine or Himalayan climate in comparison with the tremendous heat we should otherwise ascribe to the climate of the planet, there would by no means result a state of things resembling that with which we are familiar on earth. We must not, in our anxiety to people Mercury with creatures such as we know of, blind ourselves to the difficulties which have to be encountered. We cannot thin the Mercurial air, without adding to the direct effects of the sun upon the Mercurial inhabitants. Whether in this way we increase the habitability of the planet may be doubted, when we consider that the direct action of the sun's rays upon the tropical regions of Mercury, thus deprived of atmospheric protection, would produce a heat four or five times greater than that of boiling water. It will hardly be thought that the intense cold in the shade, or during the Mercurial night, would compensate for so terrible a heat. In fact, this view of the Mercurial climate would lead us to find a close resemblance between the inhabitants of the planet and the unfortunates described by Dante as doomed

> A sofferir tormenti e caldi e gieli

It would seem hard to believe in the existence of any organised forms under such conditions, unless perhaps such 'microscopic creatures, with siliceous coverings,' as Whewell proposed to people Venus with.

However, we have yet to consider whether an atmosphere of a different sort might not be better suited to the requirements of Mercury. We have seen the effects of a rare atmosphere; let us inquire into those which might be ascribed to a dense one.

The ordinary effect of a dense atmosphere we know to be an increase of heat, which is certainly not what we require in the case of Mercury. Nor are we familiar with any region upon our earth in which a dense atmosphere produces a contrary *climatic* effect; so that we have no analogy to support us in the belief that possibly a dense atmosphere might, under particular circumstances, serve to guard a planet from the solar rays. It seems possible, however, that an atmosphere might be so constituted as to remain almost constantly loaded with heavy cloud-masses. In this case it by no means follows that such effects would follow as we ordinarily associate with a moisture-laden atmosphere. Up to a certain point, doubtless, the increase of moisture in the air tends to an increase of warmth; because the aqueous vapour exercises a greater effect in preventing the escape of heat from the earth than in guarding the earth from the solar rays. And, as I have said, the only *climatic* effect we can associate with the frequent presence of large quantities of aqueous vapour in the air, or therefore with an ordinarily clouded state of the sky, is that of a general increase of heat. But, just as we know that a cloudy day is not necessarily nor even commonly a warm day, it may well be that an atmosphere so dense as to be at all times cloud-laden serves as a protection from the sun's intense heat. So that, instead of assigning dense atmospheres exclusively to the more distant planets, as some astronomers have done, we might be led to see in an envelope of great density the means of defending the inhabitants of Mercury and Venus from the otherwise unendurable rays of their near neighbour the sun.

Although Mercury is not a planet which can be satisfactorily examined with the telescope, yet, so far as can be judged from his aspect, his atmosphere is in reality much denser than our earth's, and loaded with cloud-masses of enormous extent. Still the evidence on these points is far from satisfactory; and there is one peculiarity of the planet which does not accord with this view of the constitution of his atmosphere. Undoubtedly, if the light we receive from Mercury came from a cloudy envelope, it would be more brilliant than the light we should receive from the surface of continents and oceans. In fact, the most brilliant light we could receive from a globe of a given size, placed at a given distance from the sun, would be that which would be reflected were such a globe covered with clouds. Now there can be no doubt whatever that Mercury does not reflect the same proportion of light from his surface that some of the planets do. He would be, when favourably situated, the brightest of all the planets, were this so;[1] though, seen as he always is, on the bright background of a full twilight sky, he would not make so striking an appearance as Jupiter does when in opposition. This, however, is not the case. I remember being much struck by the superior light of Jupiter, on the afternoon of February 23, 1868, when the two planets were very close together, Mercury being nearly at his brightest, whereas Jupiter, then near conjunction, was considerably less

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[1] Placing Mercury in perihelion and at his elongation, we get a half disc, the planet about 90,000,000 miles from us, and about 30,000,000 from the sun, his diameter about 3,000 miles. Now, if we wish to compare the light he then sends us with that of Jupiter at his brightest, on the assumption of equal reflective powers, we must take Jupiter at a distance of about 360,000,000 miles from us, and about 450,000,000 miles from the sun, showing a full disc, his diameter about 90,000 miles (I put all the numbers *round*, for convenience of calculation). We find, then, that the ratio of Mercury's light to Jupiter's is

$$\frac{1}{2}\,\frac{(3{,}000)^2}{(90{,}000{,}000)^2\times(30{,}000{,}000)^2} : \frac{(90{,}000)^2}{(360{,}000{,}000)^2\times(450{,}000{,}000)^2}$$

or, $\frac{1}{2}\,(4)^2\,(15)^2 : (30)^2$, or exactly 2 to 1.

The observation above cited is sufficient to prove that a very different state of things actually prevails; in other words, that the reflective powers of the two planets are very different: unless, indeed, Jupiter shines in part by inherent light.

bright than when in opposition. Venus was close by, and outshone both Mercury and Jupiter.

It seems difficult, therefore, to believe that the light of Mercury comes from a cloudy envelope. But there is still one supposition which may restore our belief in the habitability of the planet by creatures not very different from those which inhabit our earth. If it has a double cloud envelope, the upper like our cirrus clouds, less compact than the lower, and permitting a portion of the sunlight to pass through, it is possible that the lower cloud-layer would be seen partly in shadow. I must admit that the explanation is not quite satisfactory, because, just as much light as the outer clouds intercepted they would reflect; still, it is conceivable that the usual arrangement of these clouds may be such that to us, who do not look at the planet in the direction in which the sun's rays fall, but somewhat aslant, the shadows of the upper clouds upon the dense and compact lower envelope may be rendered in large part visible.

After all, the reader may prefer the view which recognises in the polar regions of Mercury places suitable for organic existences, while the equatorial and neighbouring regions are zones of fire, whose dangers the bravest Mercurials, the very Livingstones upon that planet, would not dare to face. We may picture to ourselves, on this view, the various contrivances by which the inhabitants of the two polar (that is, in reality, temperate) circles manage to communicate. There may be regions where favouring circumstances narrow the uninhabitable zone so much that the inhabitants of one polar circle may travel to the other (or, at least, cross the most dangerous portion of the hot zone) in the course of the Mercurial night. Or perhaps tunnels may be run, or sheltered cuttings made, along which the voyage may be made in comparative safety. Ocean communications there can be none, if the Mercurial skies are clear, since the sun's heat on the tropical zone would suffice to boil away any water which might find its way there.

Certainly, the smallness of the planet and the diminished effects of gravity upon its surface, would tend to make communication much easier, and the construction of protective tunnels or cuttings a comparatively light task. What the exact force of gravity at the surface of Mercury may be we do not know, because our means of determining the mass of the planet are not so satisfactory as in the case of the other primary members of the solar system. If Mercury had a satellite, we could tell his weight at once. If he were as large as Venus, we could tell his weight by observing his effect in disturbing the motions of that planet. As it is, the only means we have of weighing Mercury is the observation of his effect in disturbing any comet which may pass near him. In this way the planet has been weighed, but the balance thus employed is not a satisfactory one altogether, because we are not quite certain how much of the disturbance of a comet when near Mercury is due to the planet's attraction. Formerly it was supposed that the mean density of Mercury is equal to t of lead; but from the perturbations of Encke's met in Mercury's neighbourhood, astronomers have en led to the conclusion that the density of the net is not more than one-sixth greater than our th's. It follows that as his diameter is little more n 3,000 miles, our earth is about fifteen times as avy as Mercury. Gravity at his surface is such t a pound weight of ours would weigh rather less n seven ounces of Mercury. Hence the creatures ich seem to us most unwieldy—the elephant, the ppopotamus, and the rhinoceros, or even those vast nsters, the mammoth, the mastodon, and the mega-erium, which bore sway over our globe in far-off eras might emulate on Mercury the agility of the antelope the greyhound.

There can be no doubt that where gravity acts so bly, all engineering operations would be rendered y much simpler—bridges could have a wider span, l yet be stronger than our terrestrial ones, buildings ld be loftier and yet be raised more easily, and nsit of all sorts would be effected much more readily, ile at the same time the distances to be traversed are y much less than on our earth, since the surface of rcury is little more than one-seventh of the earth's.

The peculiarities which characterise Venus are for most part similar in kind to those we have had to nsider in the case of Mercury. But at the outset of inquiries into the physical habitudes of this most utiful planet, we must point to the striking re-earth. So far, indeed, as telescopic and physical researches have yet led us, the planet Mars, as we shall presently see, appears to exhibit habitudes more closely corresponding to those we are apt to consider essential to the wants of living creatures. But in size, in situation, and in density, in the length of her seasons and of her rotation, in the figure of her orbit, and in the amount of light and heat she receives from the sun, Venus bears a more striking resemblance to the earth than any orb within the solar system. In fact, there is no other pair of planets between which so many analogies can be traced as between Venus and the earth. Uranus and Neptune are similar in many respects, but they differ in at least as many. Jupiter and Saturn are, in a sense, the brother giants of the solar scheme, while the dwarf orbs Mars and Mercury present many striking points of similarity; but between neither of these pairs can we trace so many features of resemblance as those which characterise the twin planets Venus and Terra, while the features of dissimilarity in either pair are perhaps even more obvious than the points of resemblance. Had Venus but a moon as the earth has, we might doubt whether, in the whole universe, two orbs exist which are so strikingly similar to each other.

And here we may pause for a moment to consider one of the most perplexing enigmas that has ever been presented to astronomers. Are we indeed certain that Venus has no moon? The question seems a strange one, when it is remembered that year after year Venus as been examined by the most eminent modern ob-ervers, armed with telescopes of the most exquisite efining power, without any trace of a companion orb eing noticed. Nor indeed can any reasonable doubts e entertained respecting the moonless condition of enus by those who appreciate the character of odern telescopic observations. And yet, if I had egun this paragraph by stating the evidence in favour the existence of a satellite, I believe that nearly very reader would have come to the conclusion that ost certainly the Planet of Love has an attendant b. They are not amateur observers only who have en a moon attending on Venus, but such astronomers Cassini and Short, the latter with two different tele-opes and four different eye-pieces. Four times, be-veen May 3 and 11, 1761, Montaigne saw a body ear Venus which presented a phase similar to that of e planet, precisely as a satellite would have done. om these observations M. Baudouin deduced for the ew star a diameter of about 2,000 miles, and a distance om Venus nearly equal to that which separates the oon from the earth. In March 1764, again, Rödkier w the enigmatical companion; Horrebow saw it a w days later; and Montbaron saw it in varying posi-ons on March 15, 28, and 29. Lastly, Scheuten, who tnessed the transit of Venus in 1761, declares that saw a satellite accompany Venus across the face of e sun. So that we cannot be greatly surprised that me are still disposed to believe in the existence of a here is little occasion to dwell upon Venus's moon-ondition, because the inferior planets are much ffected by the want of a moon than a superior t would be. The service rendered by our own moon, uminary of the night, is the least important work oes in our behalf. It is as the chief regulator of ides that the moon befriends us most usefully. Venus has no need of lunar tides. Assuming he has oceans such as those which exist upon the her solar tides must be about two and a half as high as the solar tides raised in our own s. Now, since our lunar tidal wave is about two half times as high as the solar one, we have tides ng between the highest spring tides, which are and a half times as high as the solar tide alone, ne lowest neap tides, which are only one and a imes as high as the solar wave. Venus has con-tides, therefore, corresponding very closely to the tides on our own earth ; and therefore perfectly adapted to subserve all the purposes which our render us, only with less variety in their mode of tion. Mercury also has sufficiently high solar supposing he has extensive oceans (which may nably be questioned), since the smallness of his nsions (tending of course to diminish the difference ion, on which the sun's tidal influence depends) is compensated by his great proximity to that orb.

of that which separates the sun from us. Her day is about thirty-five minutes shorter than ours, and her globe somewhat smaller than the earth's.

It is clear that, merely in the greater proximity of Venus to the sun, there is little to render at least a large proportion of her surface uninhabitable by such beings as exist upon our earth. The sun, as seen in her skies, has a diameter one-third larger than he presents to us; and his apparent surface dimensions, on which of course his heating and illuminating powers depend, are greater in the proportion of about sixteen to nine. This undoubtedly would render his heat almost unbearable in the equatorial regions of Venus, but in her temperate and sub-arctic regions a climate which we should find well suited to our requirements might very well exist; while her polar regions might correspond to our temperate zones, and be the abode of the most active and enterprising races existing upon her surface.

Here, however, we have been supposing that Venus has seasons resembling our own in character—in other words, that her axis of rotation is inclined at about the same angle to the plane in which she travels. Observations have been made, according to which a very different state of things would appear to prevail. It has been said, on the authority of observers of some eminence, that her axis is inclined only 15° to the plane of her orbit.[1] If this is really the case, a number of singular and somewhat complicated relations are presented, the result of which it may be interesting to exhibit to the reader.

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[1] If the observations of De Vico may be trusted, the inclination of Venus, though less than 75°, is still so considerable (about 55°)

In the first place, the arctic regions of Venus extend within fifteen degrees of her equator (if the axis is really bowed as supposed), while the tropics extend within fifteen degrees of her poles—so that two zones, larger by far than the temperate zones of our earth, belong both to her arctic and to her tropical regions. It is difficult to say whether her equatorial, her polar, or her arctico-tropical regions would be, to our ideas, the least pleasing portion of her globe.

An inhabitant of the regions near either pole has to endure extremes of heat and cold such as would suffice to destroy nearly every race of living beings subsisting upon the earth. During the summer the sun circles continually close to the point overhead, so that, day after day, he pours down his rays with an intensity of heat and of light exceeding nearly twofold the mid-day light and heat of our own tropical sun. Only for a short time, in autumn and in spring, does the sun rise and set in these regions. A spring or autumn day, like one of our days at those seasons, lasts about twelve hours; but the sun attains at noon, in spring or autumn, a height of only a few degrees above the horizon. Then presently comes on the terrible winter, lasting about three of our months, but far more striking in its characteristics even than the long winter night of our polar

as to justify the general conclusions deduced in the following paragraphs.

ns. For, near our poles, the sun approaches the
on at the hour corresponding to noon ; and though
es not show his face, he yet lights up the southern
with a cheering twilight glow. But during the
er part of the long night of Venus's polar regions,
un does not approach within many degrees of the
on. Nay, he is farther below the horizon than the
ight winter sun of our arctic regions. Thus, un-
he skies are lit up with auroral splendours, an in-
darkness prevails during the polar winter which
add largely to the horrors of that terrible season.
inly, none of the human races upon our earth
bear the alternations between these more than
terrors and an intensity of summer heat far ex-
ng any with which we are familiar on earth.

et us see whether the equatorial regions are more
ing abodes.

n these parts of Venus there are two summers,
sponding to the spring and autumn of the polar
ns. At these seasons the sun rises day after day
e point overhead, and the weather corresponds for
e to that which prevails in the tropical regions of
wn earth. But between these seasons the sun
s away alternately to the northern and southern

During the season corresponding to summer
s above the horizon nearly throughout the 23
f Venus's day, but he attains [illegible]

n, travelling always in a small circle close around
e northern pole. During the season corresponding
winter he is above the horizon only a very short
ne each day, and is always close to the south, attain-
; only an elevation of a few degrees at noon. Thus
have the following curious succession of seasons:
the vernal equinox a summer much warmer than
tropical summers; about 56 days later, or at the
nmer solstice, weather resembling somewhat the
ing of our temperate zones, only that the night is
eedingly short; yet 56 days later there is another
nmer, as terrible as the former; and lastly, at the
nter solstice, the days are shorter and the cold pro-
bly more intense than in the winter of places near
Arctic Circles. In such regions the contrasts,
her than either of the extremes of climate, would be
st trying to terrestrial races; and it is scarcely too
ch to say that no races subsisting upon our earth
ld possibly endure such remarkable changes, suc-
ding each other so rapidly.

Lastly, the beings who inhabit the wide zones
ich are at once tropical and arctic have climates
ging between the two limits just considered. If
y are near the equatorial regions they suffer from
the vicissitudes of the equatorial climate, with this
ther tribulation, that in midwinter they do not see
sun even at mid-day—a circumstance by no means
npensated (according to our ideas) by the fact that
r the summer solstice the sun does not set. If they

terrible than the polar summer, and a winter
y less dreary and bitter.

rtunately for our belief in the habitability of
, astronomers are far from accepting with con-
e the assertions of those observers who have as-
to Venus an inclination so remarkable. If her
tion at all resembles the earth's, there is every
to believe that her physical habitudes also re-
those of the earth. In this case, the argument
nalogy, presented in the opening chapter of this
seems to force upon us the conclusion that she is
ted; while we may believe, though perhaps with
nfidence, that a close resemblance subsists be-
the creatures which people her surface and those
hich we are acquainted.

have no direct evidence, indeed, on which to
our belief that the great proximity of Venus
sun may not be accompanied by any very
able peculiarities in the characteristics of her
e. But we have an indirect argument of some
h. If Venus is much nearer than the earth
sun, the earth, in turn, is much nearer to the
an Mars is. Yet, as we shall see in the next
r, we have clear evidence from telescopic obser-
and still clearer evidence in the results of spec-
ic research, that the climatic arrangements on
o not differ in any remarkable degree from those

that, despite the claim which Dr. Whewell has put in for microscopic animalcules with siliceous coverings as the sole inhabitants of Venus, I can find no reason (if the abnormal axial inclination above considered is once disproved) for denying that she may be the abode of creatures as far advanced in the scale of creation as any which exist upon the earth.

Gravity at the surface of Venus is so nearly equal to terrestrial gravity that the difference is altogether insufficient to introduce any noteworthy effects.

Venus is the only planet the extent of whose atmosphere has been carefully estimated. If Venus had no atmosphere, she would present, when horned, a semicircular convexity; whereas the refractive effects of an atmosphere, by causing the sun to illumine rather more than a full hemisphere, would tend to lengthen her horns. It has been found that her convexity when she is horned exceeds a semicircle, and from the observed extent of this excess, it has been calculated that her atmosphere is so far more extensive than ours as to make its refractive effects on a body near the horizon about one-third greater. So that, this being about the proportion in which the diameter of the sun as seen from Venus exceeds that which he presents to us, the inhabitant of Venus, like the inhabitant of our earth, sees the sun fully raised above the horizon at the moment when, but for reflection, his orb would be just concealed beneath it.

Of the constitution of the atmosphere of Venus we know little. The spectrum of her light shows the

es which belong to the solar spectrum, and the
ecchi has noticed certain faint lines, which
indicate the presence of aqueous vapour in
osphere of the planet. But he scarcely gives
ory evidence that the lines he has thus seen
t due to the absorption exercised by aqueous
in our own atmosphere. The same observer
the strengthening of the nitrogen lines near
ne of the spectrum, evidence that the atmo-
f Venus is constituted very similarly to the
eathe.

he whole, the evidence we have points very
to Venus as the abode of living creatures not
he inhabitants of earth. With the sole excep-
he inclination, which has been, without sufficient
, assigned to the planet's equator, I can see
which can reasonably be held to point to
site conclusion. The strong light which the
rs upon Venus need least of all be objected
, if there is one adaptative power which Nature
more clearly than another, it is that by which
us creatures we are acquainted with are enabled
n comfort under all degrees of light, from the
y in which the mole pursues his subterranean
es, to the blazing light of the noonday sun
which (in fable, if not in fact) the eagle turns

nets a certain proof that reasoning beings must st who can appreciate the display. Surely the gument has very little force, since we know that riads on myriads of ages must have passed, during ich the glories of our own heavens were displayed, ght after night, with none to regard them. The on has passed through all her phases, the star of rning and of eve has shed its soft radiance upon the restrial landscape, Jupiter and Saturn have pursued eir stately courses among the fixed stars, and the ries of those constellations which shine with equal endour upon all the planets of the solar scheme ve been displayed in all their unchanging magnifi-nce, while as yet our earth was the abode but of leous reptiles, or of yet more monstrous creatures in est and in plain.

If this argument were really of force, doubtless ere are no planets in the whole range of the solar stem to which it might not be applied. Each has me special object of beauty in its heavens, which is t exhibited to the rest. Certainly Mercury and nus are no exceptions to this rule. The inhabitant Mercury sees in Venus an orb which, when favour-ly situated, far outshines in splendour the brightest the planetary orbs seen in our skies. So far, indeed, light-giving power is concerned, Venus must be no ntemptible moon to the Mercurials when she is nearly opposition. Our earth, too, with its companion on, must form a noble object in the sky of Mercury, separately visible. To the inhabitants of Venus, y and the earth must be splendid objects. The would not only appear much larger than to es, but being seen almost as favourably as we nus, would form a much more striking object in rning or evening skies of that planet. The earth, by the inhabitants of Venus, must shine much plendidly than Jupiter does in our skies. Our must be distinctly visible, so that, without the ny telescope, the inhabitant of Venus has such e of the Copernican theory as would suffice, if y handled, to rout the ranks of the Ptolemaists, ng there have ever been people in Venus who ed the tiny globe they live upon to be the of the universe.

CHAPTER IV.

MARS, THE MINIATURE OF OUR EARTH.

' is singular that, among all the orbs which circle
ound the sun, one only, and that almost the least of
ie primary planets, should exhibit clearly and unmis-
kably the signs which mark a planet as the abode
' life. We have examined Mercury and Venus, the
ıly other orbs which belong like the earth and Mars
› the scheme of the minor planets, and we have found
ttle to guide us to any certain conclusion respecting
ıeir physical habitudes. When we pass beyond the
ide gap which separates the minor planets from the
ant members of the solar family, we shall find much
› attract our admiration, much to force upon us the
elief that these orbs have been created to be the
oodes of even nobler races than those which subsist
pon our earth; but we shall find little to justify us in
sserting that they resemble the earth in those habi-
ıdes which seem essential to the wants of terrestrial
ıces. The planet Mars, on the other hand, exhibits
ı the clearest manner the traces of adaptation to the
ants of living beings such as we are acquainted with.
rocesses are at work out yonder in space which

utterly useless, a real waste of Nature's energies, like their correlatives on earth, they subserve nts of organised beings.

ould not indeed insist, as some have done, too y upon this argument. I know that on every see tokens of an exuberant activity in Nature, according to our ideas, may appear to savour of lness. The cloud which has been raised by ar energies from tropical seas, and which the have wafted over continents, may shed its on the sea or in the desert, where seemingly re wholly wasted. Winds may spend their pparently in vain. And in a thousand ways 's busy forces may be at work where we, in our ghtedness, can see no useful purpose which they e.

there is a marked distinction between such ap- instances of wasteful action, and the systematic es which are taking place over the globe of

on our earth we can dimly trace out a necessity ding upon the order which actually exists) for hich appears to resemble waste. We see, for e, that if a country or a continent is to be pro- vith a due supply of rain, without supernatural ntion at every step of the process, that result ly be secured by what may be described as a serve to explain (so to speak) the seemingly wasted ones.

In the case of Mars we have no such explanation of the processes we observe, if we dismiss our belief that he is the abode of living creatures. For if Mars be, indeed, untenanted by any forms of life, then these processes, going on year after year and century after century, represent an exertion of energy which appears absolutely without conceivable utility. If one cloud out of a hundred of those which shed their waters upon Mars supplies in any degree the wants of living creatures, then the purport of those clouds is not unintelligible; but if not a single race of beings peoples that distant world, then indeed we seem compelled to say that in Mars at least Nature's forces seem wholly wasted.

Let us consider what astronomy has taught us respecting the ruddy planet.

The globe of Mars is about 5,000 miles in diameter, so that his linear dimensions bear to those of the earth the proportion of about 5 to 8. His surface, therefore, is less than that of the earth in the proportion of about 25 to 64, or more exactly (and more conveniently), the surface of the earth is 2½ times as extensive as that of Mars.

The substance of Mars has an average density rather less than three-fourths of our earth's, or very nearly four times that of water. Thus gravity at his surface is much less than terrestrial gravity. It is even less, in fact, than gravity at the surface of Mercury, h that one of our pound weights placed at the of Mars would weigh but 6 oz. 3 dwts., instead 7 ounces, as on Mercury. I have already dwelt effects of such a relation as this, and shall have , when describing the condition of Jupiter, to the converse relation. But I may remark, in how singular it is that we should be compelled e the smallest planets with the largest inhabit- we wish to bring the inhabitants of different about the same scale of activity. A Daniel t on Mars would be able to leap easily to t of five or six feet, and he could run faster e best of our terrestrial athletes. A man of ht, but proportioned more suitably for athletic s, could leap over a twelve-feet wall. On the and, a light and active stripling removed to would be scarcely able to move from place to On the sun his own weight would simply m to death.

s travels in an orbit of considerable eccentricity; the centre of his orbit is no less than 13,000,000 om the sun. Accordingly, the light and heat ves from that luminary vary to an important In fact, he gets about half as much heat and ain when in perihelion as when in aphelion. cumstance affects to an important extent the relations of his two hemispheres, as we shall proportion of about 4 to 9. The length of his year also constitutes a noteworthy circumstance in which his habitudes differ from those of our earth. His year contains very nearly 687 of our days, so that each of the Martian quarters lasts about 5⅔ of our months. But, owing to the eccentricity of his orbit, the winter and summer of the northern and southern hemispheres are not equal. The Martian day is nearly forty minutes longer than ours.[1]

His equator is inclined at an angle of about 27¼ degrees to the plane of his orbit, and as the corresponding inclination in the case of the earth is about 23½ degrees, it will be seen that his seasonal changes do not differ much in character, so far at least as they depend on inclination, from our own.

The axis of Mars is so situated that the summer of his northern hemisphere occurs when he is at his greatest distance from the sun. The same relation holds in the case of the earth, the sun being 1,500,000 miles nearer to us in winter than in summer, whereas, to those who live in the southern hemisphere, he approaches nearer in summer than in winter. But the effects resulting from the relation in the case of Mars

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[1] More exactly, the length of the Martian day is 24h. 37m. 22·7s. This estimate I have obtained by comparing pictures taken by Hooke in 1666, and by Dawes and Browning in 1866–69—taking precautions to secure that no complete rotation should anywhere be lost sight of. Kaiser obtained a period differing only one-tenth of a second from mine; but even this small discrepancy is removed when certain clerical errors in Kaiser's work (as his counting 1700 and 1800 as leap-years, and wrongly correcting for change of style) are removed.

ust be very much more striking than those we re-
gnise. For whereas the sun gives only one-fifteenth
ore heat to the whole earth in January than he does
July, the sun of Mars gives half as much light
ain in perihelion as in aphelion. The summer of
e northern hemisphere of Mars must be rendered
uch cooler and the winter much warmer by this ar-
ngement. On the other hand, the contrast between
e summer and winter of the southern hemisphere is
ndered more striking than it otherwise would be.

It is, however, the telescopic aspect of Mars rather
an relations such as we have been dealing with that
fords the most interesting evidence respecting the
ness of the planet to be the abode of living crea-
res. Although the least but one among the primary
anets—a mere speck compared with Jupiter and
turn—Mars has been examined more minutely and
nder more favourable circumstances than any object
the heavens except the moon. He does not ap-
oach us so closely as Venus, nor does his disc appear
large as Jupiter's, yet he is seen more favour-
ly than the former planet, and on a larger scale, in
ality, than the latter. In fact, whereas Venus is
e of the most unsatisfactory of all telescopic ob-
cts, Mars is one of the most pleasing; and whereas
piter is always more than 380,000,000 of miles from
, Mars sometimes approaches us within less than
,000,000 of miles.

Yet even this distance is enormous, and it affor scopes are constructed and used that astronomers should have been able to span that mighty gulf, and to bring from beyond it reliable information respecting the structure of so distant a world.

Such information has been brought, however, and is full of interest.

Viewed with the naked eye, the most remarkable feature Mars presents is his ruddy colour. In the telescope this colour is not lost, but instead of characterising the whole surface of the planet, it is confined to particular regions—the intermediate parts being for the most part darker, and of a somewhat greenish hue. But a noteworthy feature adds largely to the beauty of the picture presented by the globe of Mars. Two bright spots of white light are seen on opposite sides of his disc, presenting precisely such an appearance as we might imagine the snowy poles of our earth to exhibit to an astronomer on the planet Venus.

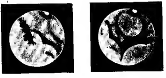
Towards the edge of the disc the ruddy and the greenish tracts are lost in a misty whiteness, which grows gradually brighter up to the very border of the planet. This peculiarity, as will be seen, is one of the most instructive features of the planet's aspect.

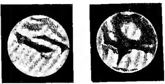
In August 1877 two minute moons were discovered which travel around Mars in about 30¼ hours and about 7⅔ hours respectively.

It was discerned, more than two hundred years ago, that the reddish spots on Mars, and the darker regions which lie between them, are not accidental or variable phenomena, but represent permanent peculiarities of the Martian surface. Cassini, with one of those outrageously long telescopes which were used before the invention of achromatic refractors, was the first to discover this. But the ingenious Hooke seems to have obtained better views of Mars in 1666. At least, his pictures of the planet are the only ones taken in the seventeenth century in which I can recognise the now well-known aspect of the Martian continents and oceans.

Later, Maraldi and the Herschels, Arago, Secchi, Kunowski, Beer, and Mädler, and a host of other eminent astronomers, have not thought the study of this planet's aspect beneath their notice. Within the last few years, also, this work has been prosecuted by Dawes, Green, R. Trouvelot, and others. Dawes, whose acuteness of vision earned for him the title of the 'eagle-eyed,' took so many and such admirable views of the planet as to render it possible to form a globe of Mars. Sir William Herschel had chartered the planet, and Messrs. Beer and Mädler had made improved Martian maps; while Phillips had constructed two globes of Mars in which many features were presented. But Mr. Dawes's pictures of the planet were sufficient, when carefully compared, for the formation of a globe in which no large area of the planet should be left bare of details. He entrusted to me no less than twenty-seven drawings of Mars, the choicest specimens of a very large series, that I might chart the planet from them. From the study of his drawings the accompanying chart has been formed. Of the four illustrative views the

MARS IN 1877 (*Trouvelot*).





MARS IN 1877 (*N. Green*).

by Mr. Nath. Green. The chart of Mars, in the darker parts of the planet are assumed to as and the lighter tracts continents, exhibits esults obtained from the study of the complete This chart is on Mercator's projection, and erted—the south polar regions, that is, are at op—because the telescopes commonly used by ers exhibit inverted views of the celestial ob- At the top of the map we see the icy region lies at the southern pole of Mars. Around region is a sea unnamed in the maps. Then the southern temperate zone there lie several of Martian land, named after observers of the . These regions appear to form a continuous elt round the temperate zone; though there ne uncertainty on this point, owing to the fact ne coast-line is not often very distinctly visible. ow approach, however, a part of the map where e features are thoroughly recognised and perma- Next to the circle of land just described there early complete circle of water, one strip only of connecting the equatorial continents of Mars the south temperate zone of minor continents. ning at the eastern or left-hand extremity of map, we have a long sea called Maraldi Sea el to which runs Hooke Sea, trending in a westerly direction and so running into Dawes

Rue Ocean, communicating by narrow straits with two strikingly similar seas. Here the zone of water ends, and we have only to note further respecting it that in De la Rue Ocean there is a large island, which presents so strikingly brilliant an aspect that it has been supposed to be covered (ordinarily) with snow. It has been called Dawes's Ice Island.

I now come to the most remarkable feature of the Martian geography—or perhaps I ought rather to say, *areography*. This is the great equatorial zone of continents. There are four of these. On the left of the map is Herschel I. Continent. Next is Dawes Continent, the largest of the four, and separated from the former by a long sea called Kaiser Sea. This sea is one of the most striking marks on the planet, and has been recognised from the earliest days of telescopic observation. It is connected towards the east with a flask-shaped sea, somewhat resembling the two which lie at the western extremity of the zone of water just described. At its northernmost end it turns sharply westward, and forms the southern boundary of Dawes Continent. Further west lies Mädler Continent, separated from Dawes Continent by a long strait, which runs almost directly north and south. Lastly, there is Secchi Continent, separated from Mädler Continent by Bessel Inlet and from Herschel Continent by Huggins Inlet. A large lake on the last-named continent is worthy of notice on account of its singular

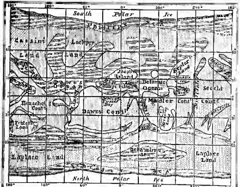


Chart of Mars

The northern half of Mars has not been so tho- ighly examined as the southern, for a reason which l presently be mentioned. It is known, however, it, in all essential respects, it resembles the southern misphere. Next to the equatorial zone of continents ere comes a zone of water, expanding at one point o Beer Sea, and at another into Tycho Sea. Then nes a zone of land, called Laplace Land, in which s an enormous lake called Delambre Sea. Next is arrow zone of water, called the Schröter Sea: and we reach the north polar ice-cap.

I have been speaking of the spots on Mars as ough they undoubtedly represented land and water. t many may be disposed to question the evidence have on this point—to ask why the ruddy spots ould be held to be continents or islands, and the eenish-coloured markings to be oceans, seas, and es. We know that for a long time after the in- ntion of the telescope, astronomers called the darker rtions of the moon, *seas*. They spoke of the Sea of renity, the Sea of Crises, the Sea of Humours, and on; and we know now for certain that these dusky gions are not seas. It may be asked, therefore, how can feel certain that the dark spots on Mars are eans.

At first sight this question seems a difficult one answer. The most powerful telescopes have been ected towards the moon, without affording any isfactory information respecting the condition of ost favourable circumstances—more than one d and sixty times farther from us than the moon, be thought to be altogether beyond the reach telescopists—so far, at least, as any knowledge Martian surface is concerned. But one im- distinction between Mars and the moon must efully attended to. The surface of the moon is the same—no natural processes seem ever to lace over that scene of desolation, though the s exposed to contrasts of temperature, compared hich the distinction between the intensest heat summers and the bitterest cold of our winters altogether evanescent. But on Mars the case inly different. Whatever opinion we may form ing Martian habitudes, whether we assume or t Mars is the abode of any forms of animal life, an be no question whatever that physical pro- of change are taking place on a grand scale in stant world. Many evidences of this can be at dduced. We have spoken of the Martian fea- s constant. They differ, for instance, from the gs on Jupiter, which are as changeful as the of our April skies. But though the same g may have been seen by Hooke in 1666, by i in 1720, by Herschel in 1780, by Beer and in 1830–37, and by Dawes in 1852–65, yet it neans follows that it is always visible when the e distinctness or indistinctness with which our own mosphere permits us to see the planet. A spot will blurred and indistinct when a neighbouring marking exhibited with unusual clearness.

Let us consider an instance of this peculiarity. On ctober 3, 1862, late in the evening, a part of Dawes cean, where it borders on Herschel Continent, was dden from view. In place of the ordinarily dark pect of this region, a faint, misty light, with ill-efined borders, was observable. As the evening proessed the outlines gradually became clearer, but at out half-past eleven the white light still continued veil the outline of a part of Dawes Ocean. But Mr. awes, observing Mars at a quarter past twelve, und that the process of clearing up noticed in e earlier part of the night had entirely lifted off e veil which concealed the coast-line. The remains the misty light seen earlier are still to be detected Mr. Dawes's drawing, but they have passed farther uth, and no longer hide the shores of Dawes Ocean.

The Padre Secchi of the Collegio Romano states at he has often noticed similar appearances while serving Mars with the fine refractor in the observary of that institution.

But yet another peculiarity of the same sort remains be mentioned. Mars, as I have said, has his winter d summer seasons. Since we know the position of e Martian equator upon his surface, we can tell what ason is in progress in either hemisphere at any given hemisphere, and therefore summer in the other, rmer hemisphere is nearly always hidden from y just such a veil as I have spoken of above.

nay remark, in passing, that this peculiarity has ny observers to form very erroneous impressions ting the distribution of land and water over the of Mars. Seeing one hemisphere covered for together with whitish light, they have concluded here are no oceans there; and if they have no pportunity of observing the planet, the mistaken sion remains, and is published to the world with authority of the observer's name.

w, what is this veil which sometimes for a few or days, at others for months together, is drawn ne features of the Martian globe? Have we any rial analogies by means of which we may interhis phenomenon?

answer these questions, let us conceive the f an observer on Venus watching our earth. such an observer always see the features of lobe with equal distinctness? When heavy of cloud are drawn over a wide expanse of y—spreading often, as meteorologists record, for eds, and even thousands of miles—can we suppose ne astronomer on Venus could pierce through l? Since we cannot see the bright body of the rough a dense cloud-veil, we may be certain that this globe would be to him, at such a time, as though they were not.

Here, then, we have an argument from analogy for supposing that the veil, which from time to time conceals the Martian features, may resemble terrestrial cloud-banks. Let us next inquire whether there is anything in the behaviour of the Martian veil to justify this view.

It is clear that if we held the concealing medium to be of a cloudy nature, the disappearance of the features of the hemisphere which is passing through the Martian winter would indicate that in winter the Martian skies are more clouded than in summer. We know that this is the case on our own earth, that fogs and mists, clouds, rain, and snow, are phenomena far more frequently observed in winter than in summer. We know also why it is so. The cold winter air is unable to retain the aqueous vapour continually passing into it, and is thus forced to precipitate this vapour in one or other of the forms just named. Nor can we see any reason why the Martian atmosphere, supposing it to resemble our own, should not act in precisely the same manner. Thus we recognise, in the remarkable seasonal peculiarity above described, what seems to be the exact counterpart of processes recognised upon the earth.

Perhaps the reader may be disposed to inquire whether the clearing up of a portion of the Martian disc observed by Dawes admits of interpretation in a similar way. To this it may be replied that, from the observed position of the region in question, the Martian f *day* there must have been somewhere about nd about one o'clock in the afternoon (according terrestrial mode of reckoning) when Mr. Dawes ed the planet. It is no uncommon thing to see restrial skies clear up soon after mid-day; and veil which conceals the Martian features is really , this is precisely what happened out yonder, millions of miles away from us, on the day in n.

hink the reader will at least concede that the ation here given of these peculiarities is more l than one which was put forward some time by an eminent French astronomer. He urged Iartian vegetation, instead of being green like s red; hence in the Martian summer, the surface, n by us, assumes a ruddy aspect, while the hemisphere loses its ruddy tint. According interpretation, such changes as were noticed by would indicate the sudden blooming forth of n vegetation over hundreds of square miles of rtian surface!

the evidence already dealt with may be added hich is afforded by the whiteness of the disc s near the edge. Knowing that the parts of vhich thus appear concealed in mist are those it is morning or evening to the Martians, we lose analogy here to terrestrial relations, since

I may here pause, in passing, to notice under what fficulties the observation of Mars is conducted by he terrestrial observer. To begin with, the sky must e exceptionally clear; and none but the practised bserver knows how seldom there occurs what is called a good observing night.' Then it must be *a fine day r the Martians*, for clouds over Mars, or even an imerfectly clear atmosphere, must produce quite as bad n effect in spoiling the definition of Martian features similar phenomena on earth. Again, Mars only omes into a favourable position once in every two and quarter years, continuing to be well placed for only few months. Thus it happens that, although Mars as been telescopically observed for more than two undred years, the actual time during which he has een favourably placed for observation has been very uch less; and taking into account all the requireents for good definition, it may be said that Mars as not been under really effective observation for ore than a very few days.

Of course if we admit that the vaporous envelope hich occasionally hides parts of Mars is aqueous, we ust believe in the existence of oceans upon Mars. nd from our knowledge of the appearance of our wn seas, we should immediately recognise the greenish

cated a subsidiary explanation of this peculiarity, founded on e probable shape of the Martian clouds. For the same reason at, near the horizon, our own cumulus clouds seem more closely cked than overhead, the Martians would see a clearer sky overad than near the horizon. It follows at once that we should see st those parts of the surface of Mars which we look down upon f Mars as the Martian oceans, and look upon ldy parts as continents. We have seen that the ur of the various envelopes corresponds to f our own clouds and fogs. But it might be t possible that the vapours arise from fluids han water; that, in fact, a state of things exists Iars wholly different from that which prevails r own earth.

ew years ago it would have been very difficult to e such an argument as this, however fanciful it em. But the wonderful powers of the spectro-ave been applied to this question, and there is taking the results which have been obtained. st premise that this is hardly a favourable case application of spectroscopic analysis, which (as e to the astronomer) deals most effectively with inous objects. Still, there was a possibility e light which comes from Mars might have been l upon by vapours in the Martian atmosphere spectrum would be affected in an appreciable .

Huggins examined Mars in 1864 without satis-results, but at the opposition of Mars in 1867 more successful. In the following description most striking observation I epitomise his . On February 14 he examined Mars with a scope attached to his powerful 8-inch refractor.

solar spectrum when the sun is low down so that its light has to traverse the denser strata of our atmosphere.' To determine whether these lines belonged to the light from Mars or were caused by our own atmosphere, Mr. Huggins turned his spectroscope towards the moon, which happened to be nearer the horizon than Mars, so that the atmospheric lines would be stronger in the moon's spectrum than in that of the planet. But the group of lines referred to was not visible in the lunar spectrum. Hence it was clear that they belong to the Martian atmosphere, and not to ours.

I have said that these lines appear in the solar spectrum when the sun is shining through the denser strata of our atmosphere; so that the Martian atmosphere must contain at least those constituent vapours whose existence in our atmosphere causes the appearance of these lines in the solar spectrum. Hence there must be *some* similarity between the Martian atmosphere and our own. But we know from the researches of the Padre Secchi that it is the aqueous vapour in our air which causes the appearance of the lines in question. Hence there must be aqueous vapour in the Martian atmosphere.

The discovery at once justifies the title of the present chapter. Let us consider what a number of interesting results follow from it.

The water in the Martian air must be raised from seas and rivers upon the planet. These, therefore, consist of water, and not of other fluids. The two e spots, then, on the Martian disc are no longer tful appearances. Before the discovery that water s on Mars it was perhaps somewhat bold to proce that these spots certainly indicate the presence -fields around the Martian poles, resembling those n exist around the poles of the earth. Sir William chel, indeed, with that confidence which he always ed when he had a trustworthy analogy to guide came to this conclusion on the strength of the spondence between the changes of the two spots the progress of the Martian seasons. But many nomers felt that there was still room to doubt her he could really speak of the spots as—

> The snowy poles of moonless Mars.

however, we know that they can be no other snow-caps. Nay, if Mars were so far off that we not distinguish these spots, we could yet, on the gth of what the spectroscope has taught us, unce confidently that his polar regions must e-bound.

et us proceed a step or two farther. We have that there are oceans on Mars; we know that s and vapours arise from those oceans, and are d over his continents; and finally, we have learned snow falls on the Martian polar regions. These are very interesting in themselves, but they ate the occurrence of processes yet more inter-our earth. The heat of the sun's rays is used up, so speak, in raising aqueous vapour from the surface the ocean. Thus the air is rendered cooler than it herwise would be, and this takes place just where olness is most needed. But the aqueous vapour, ice raised, is swept by the winds to other regions. So ng as the air remains warm the aqueous vapour reains unchanged; but so soon as it has been carried colder regions it is condensed into the form of a cloud mist, and while changing to this form it parts with e heat which had turned it into vapour. Thus where eat is in excess, it is used up in forming aqueous ipour; and where heat is wanted, there the aqueous ipour distributes it.

We see, then, that on Mars there exists the same lmirable contrivance for tempering climates which we nd on our own earth.

But let us consider yet another office fulfilled by queous vapour. It not only serves to convey the eat from the warmer parts of the earth to those gions where heat is most needed; it forms clouds hich serve to shelter the earth from the sun's heat by y, and to prevent the escape of the earth's heat by ght, which also, in refreshing rains, 'drop fatness the earth.' Now the clouds on Mars are certainly ssipated in some way, because, as I have said, tronomers have repeatedly seen them disappear. nd doubtless, like our own clouds, they are often ssipated by the sun's heat. But we may take it for ed that, like our terrestrial clouds, they are also dissipated by falling in rain. Thus the Martian are nourished by refreshing rainfalls; and who ubt that they are thus nourished for the same se as our own fields and forests—namely, that tion of all sorts may grow abundantly?

t yet again, the transit of clouds from place to implies the existence of aërial currents. Clouds indeed even form and be dissipated without oning wind-currents; and it need hardly be said he Martian clouds could not be carried to his regions, there to fall in snow, unless the atmo- c currents on Mars were extensive and persistent. e, then, that Mars has winds as our earth has. less his trade-winds are less marked than ours, se his surface rotates less rapidly than the earth's, be being much smaller, while his rotation-period htly greater. But he has less need for trade- his oceans being so much less extensive than No Columbus on Mars has ever needed the ent breath of easterly winds to encourage him voyage to an undiscovered continent. Rather, tricate navigation of the narrow Martian seas be favoured by variable breezes. But the purposes which the circulation of our own here subserves are subserved efficiently out on Mars. The air is cleansed and purified, surface on which they are projected is partially self-luminous.

A stronger argument against the belief that Jupiter is self-luminous lies in the fact that the satellites disappear in his shadow. It must be remembered, however, that in any case we can assign but a small proportion of inherent light to Jupiter, and that his satellites would therefore, in any case, lose so large a proportion of their light when passing into his shadow that we might expect them to disappear, even under the closest telescopic scrutiny.

One of the most surprising phenomena ever witnessed by the telescopist seems to me to afford even stronger evidence than any yet adduced. I refer to the observation made by Admiral Smyth, that on one occasion the second satellite of Jupiter, twelve minutes after entering on the disc of the planet, was seen *outside the limb*, 'where it remained four minutes, and then suddenly vanished.' Two other equally competent observers, Maclear and Pearson, witnessed the same phenomenon. 'Here,' says Webb, 'explanation is set at defiance.' But it is precisely where explanation seems set at defiance that we have reason to be most hopeful of gaining instruction. The observation is very startling, it is true; and the explanation may be expected to be also surprising. But I think it is not far to seek. The satellite cannot have retraced its course; Jupiter cannot have shifted his place; our atmosphere cannot be in question: all these explanations being eliminated, our task is rendered easier for which, like our own, it has doubtless been created.

We may trace yet farther, however, the results which follow from the existence of aqueous vapour in the atmosphere of Mars. We see the polar snows aggregating in the Martian winter and diminishing in the Martian summer. And we know that, on our own earth, the increase and the diminution of the polar snows are processes intimately associated with the formation and maintenance of the oceanic circulation. Doubtless much yet remains to be done before that system of circulation will be fully understood. The rival views which have been maintained by Sir John Herschel and Captain Maury have served to throw a certain air of doubt over the theory of ocean currents.[1] But whether we ascribe the equatorial currents of our oceans to the trade-winds, with Herschel, or to differences of specific gravity, with Maury, we see that, in the first place, both causes operate in the case of Mars;

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[1] If Herschel has completely overthrown Maury's theory, that currents are altogether due to differences of specific gravity, saltness, and so on, Maury has at least been as successful in overthrowing Herschel's theory, that the currents are due to the trade-winds. A theory more probable than either is, I think, that according to which the whole system of circulation is set in motion by the continual evaporation going on in equatorial seas. Thus, by a process resembling suction, an in-draught of cold water is caused, and this water coming from higher latitudes, where the earth's eastwardly motion is less, to lower latitudes, where the eastwardly motion is greater, produces the relatively cold and westwardly equatorial currents which exist in the Atlantic, Indian, and Pacific Oceans. Recent researches into the temperature of the deep sea have tended strongly to confirm these views, which I dealt with at some length in the second volume of my 'Light Science for Leisure Hours.'

ondly, that the submarine return-currents from r regions must, at any rate, be due to the of ice in the polar seas. So that undoubtedly ian oceans, so far as their peculiar conforma- permit, are traversed by currents in various s and at various depths.

n, lastly, there must be rivers on Mars. The hich often hide from our view the larger part rtian continent indicate a rainfall at least as ible (in proportion) as that which we have on n. The water thus precipitated on the Martian ts can find its way no other wise to the ocean ng river courses.

o the nature of these rivers, again, we may form res founded on trustworthy analogies. The stence of continents and oceans on Mars proves on of forces of upheaval and of depression. must be volcanic eruptions and earthquakes g and remodelling the crust of Mars. Thus ist be mountains and hills, valleys and ravines, ds and watercourses. All the various kinds y which make our earth so beautiful have their tatives in the ruddy planet. The river courses ean, by cataract and lake, here urging its way sly over rocks and boulders, there gliding tely flow along its more level reaches. The peeds to the river, the brook to the rivulet, and things are meant to teach us? So far, let it be remembered, we have been guided onwards by no speculative fancies, but simply by sober reasoning. But shall we recognise in Mars all that makes our own world so well fitted to our wants—land and water, mountain and valley, cloud and sunshine, rain and ice and snow, rivers and lakes, ocean-currents and wind-currents—without believing further in the existence, either now, or in the past, or in the future, of many forms of life? Surely, if it is rashly speculative to form such an opinion respecting this charming planet, it is to speculate still more rashly to assert that Mars is not, has never been, and never will be, tenanted by living creatures, or by any beings belonging to other than the lowest orders of animated existence.

CHAPTER V.

UPITER, THE GIANT OF THE SOLAR SYSTEM.

G over the zone of asteroids, we come now to blest of all the planets—the giant Jupiter. If s to be the measure of a planet's fitness to be ode of living creatures, then must Jupiter be in- d by the most favoured races existing through- e whole range of the solar system. Exceeding rth some 1,230 times in volume, and more than mes in mass, this magnificent orb was rightly d by Brewster as the crowning proof of the e insignificance of the earth in the scale of n.

if we estimate Jupiter rather by the forces in- in his system, if we contemplate the enormous y with which his vast bulk whirls round upon s, or trace the stately motion with which he onward on his orbit, or measure the influences ich he sways his noble family of satellites, we are

The very symmetry and perfection of the system ich circles round Jupiter have led many to believe t he must be inhabited by races superior in intelli- ce to any which people our earth. The motions of se bodies afford, indeed, to our astronomers a noble ject of study. Our most eminent mathematicians e given many hours of study to the phenomena ich the four moons present to the terrestrial ob- ver. But we can trace only the general movements he satellites of Jupiter. Their minor disturbances, effects of the varying influences which the sun and iter exert upon them, and which the moons exert n each other, must tax the powers of far abler thematicians even than he who 'surpassed the whole nan race in mental grasp.'

But after all, we must judge of Jupiter rather ording to the evidence we have, and the analogies ch are most directly applicable to the case, than ording to fancies such as these. We know that the , which surpasses Jupiter in weight and volume n more than Jupiter surpasses the earth, is yet the abode of life, so that mere size and mass st not be held to argue habitability. We know t many meteors and comets sweep through space re swiftly than the vast bulk of Jupiter, so that the rgies indicated by mere velocity of motion, whether ital or rotational, must be equally disregarded. must we forget that, ages before men studied the tions of our own moon, she presented the same ams, a Leverrier, or a Delaunay. Even now a nd grand problems are presented to our men of which escape their notice, and we might as ably argue that there must be creatures existing eived amongst us, who deal with these problems, , out yonder in space, there must be beings who he complicated motions of the Jovian satellites.

piter presents the following principal physical des:—

has a diameter of about 85,000 miles, or nearly es as large as the earth's, a surface 115 times and, as I have said, a volume more than 1,200 arger. Gravity at his surface is about two and times as great as on our earth's, so that such res as exist around us would find their weight more than doubled if they were removed to r. He lies more than five times farther from the an our earth, and the light and heat which he s from that orb are reduced to about one-twenty- our supply. He rotates on his axis in rather less en hours (9 hours 55 minutes 26 seconds), so e length of his day is considerably less than half s. His axis is nearly perpendicular to his orbit, t there are no appreciable seasonal changes as eeps round the sun in his long year of 4,332½

will be convenient to consider, first, the probable

The grandeur of his orb naturally suggests, at first sight, the idea of beings far exceeding, both in might and bulk, those which live upon the earth. Old Wolfius was led to a similar conclusion in another way. I quote his quaint fancies as quaintly presented by Admiral Smyth. 'Wolfius,' says the genial sailor, 'not only asserts that there are inhabitants in Jupiter, but also shows that they must necessarily be much larger than those of the earth; in fact, that they are of the giant kind, and nearly fourteen feet high by *eye-measurement*. And thus he proves it. It is shown in optics that the pupil of the eye dilates and contracts according to the degree of light it encounters. Wherefore, since in Jupiter the sun's meridian height is much weaker than on the earth, the pupil will need to be much more dilatable in the Jovian creature than in the terrestrial one. But the pupil is observed to have a constant proportion to the ball of the eye, and the ball of the eye to the rest of the body; so that, in animals, the larger the pupil the larger the eye, and consequently the larger the body. Assuming that these conditions are unquestionable, he shows that Jupiter's distance from the sun, compared with the earth's, is as 26 to 5; the intensity of the sun's light in Jupiter is to its intensity on the earth in a duplicate ratio of 5 to 26.' The eyes of the Jovians and their dimensions generally must be correspondingly enlarged, and 'it therefore follows that even Goliath of Gath would have cut but a sorry figure among the natives of Jupiter. That is, supposing the Philistine's altitude to be some-

between eight feet and eleven, according as we
o Bishop Cumberland's calculation, or the Vatican
of the Septuagint. Now, Wolfius proves the
f the inhabitants of Jupiter to be the same as
f Og, king of Bashan, whose iron camp-bed was
cubits in length and four in breadth—or rather
ows, in the way stated, the ordinary altitude
e Jovicolæ to be $13\frac{819}{1440}$ Paris feet, and the
of Og to have been $13\frac{1296}{1440}$ feet. See his Works,
. p. 438.'

is exact determination of the dimensions of Jovian
vould be very pleasing and satisfactory were it
at another line of argument guides us at least as
sively to a very different view. If we are to
e that beings resembling men in all attributes
size actually exist on Jupiter, we might claim for
beings the power of moving from place to place
ely as we do, with quite as much reason as
as claimed for them the same powers of vision
ve possess. Proceeding according to this view,
e led to the conclusion that the *Jovicolæ* are
es about two and a half feet, on the average, in
. For we know that a man removed to Jupiter
weigh about two and a half times as much as he
on our own earth. He would thus be oppressed
burden equivalent to half as much again as his
veight. This would render life itself an insup-

portioned varies as the third power of the height;
example, a body twice as high as another—in other
ects similar—will be eight times as heavy. But
muscular power of animals varies as the cross
tion of corresponding muscles, or obviously as the
are of the linear dimensions; so that of two animals
ilarly constituted, but one twice as high as the
er, the larger would be four times the more power-
He would weigh, however, eight times as much
the other. He would therefore be only half as
ve. Similarly, an animal three times as high as
ther of similar build, would be only one-third as
ve; and so on for all such relations. Now, since a
restrial man removed to Jupiter would be two and
alf times as heavy as on the earth, it follows, ob-
usly, that a man on Jupiter proportioned like our
restrial men would be as active as they are, if
height were to theirs as one to two and a half.
nce, setting six feet as the maximum ordinary
ght of men on the earth, we see that the tallest and
dsomest of the Jovicolæ can be but about two and
alf feet in height, *if only our premisses are correct.*
us Tom Thumb and other little fellows, if removed
Jupiter, might be wondered at for their enormous
ght, and eagerly sought after by any Carlylian
dericks who may be forming grenadier corps out
der.

One line of argument having thus led us to regard
Jovicolæ as Ogs of Bashan, while another equally

ar-old children, we may fairly conclude that ethod of reasoning is fallacious. We must not re the inhabitants of other worlds according conceptions suggested by the forms of life we quainted with upon earth. We must admit the lity that arrangements as different from those familiar with as the constitution of the insect that of man may be presented amid the orbs circle round the sun. It were unwise, no doubt, e free scope to speculation where we have, in no means of forming an opinion. We need not e, as some have done, that 'the inhabitants of r are bat-winged,' or, with others, 'that they veterate dancers.' Nor, to take the views of respectable authorities, need we agree with Sir bry Davy that the bodies of the Jovians are sed of 'numerous convolutions of tubes more ous to the trunk of the elephant than anything with Whewell, that they are pulpy, gelatinous res, living in a dismal world of water and ice with ery nucleus; nor finally, with Brewster, that the may have his 'home in subterranean cities d by central fires, or in crystal caves cooled by tides, or may float with the Nereids upon the or mount upon wings as eagles, or rise upon the s of the dove, that he may flee away and be at *sic*). So soon as we give a definite form to the

deous, or the ridiculous.[1] It is sufficient to recog-
se the probability, or rather the certainty, that the
ings of other worlds are very different from any we
e acquainted with, without endeavouring to give
ape and form to fancies that have no foundation in
ct.

We may regard it as probable, however, that living
eatures in Jupiter, if any exist, are built generally
a much smaller scale than those which people our
rth. Trees, plants, and the vegetable world gene-
lly, must also, one would imagine, be very differently
nstituted from those we are familiar with. It is
ell known that the motion of the vegetable juices is
part regulated by the force of gravity, and therefore
must be admitted that the structure of terrestrial
ants is in part dependent upon the value of gravita-
on at the earth's surface. Whewell, in his 'Bridge-
ater Treatise' on the astronomical evidence of design
creation, lays great stress on this relation, pointing
t, if I remember aright, that all vegetation would be

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[1] It may be worth while to gather a lesson from this circum-
nce. We know that every form of life is replete with evidences
adaptation (no matter how secured) to the conditions which sur-
und it. Now man, with all his knowledge of these adaptations,
soon as he passes the boundary of the known, pictures to himself
manner of unnatural and impossible forms of existence. Even
e unknown parts of our own earth have been peopled ere now, in
agination, with 'men whose heads do grow beneath their shoul-
rs,' and other similarly incongruous beings. It is more excusable,
rhaps, that an anatomically impossible structure should have been
igned to angels: (the cherubim have been even more unfortunate)
ile Satan, who 'goeth about as a roaring lion,' has had the pri-

ed at once if there could suddenly take place
rked change in the earth's attractive forces.
view is correct, it is certain that none of our
ould thrive on the soil of Jupiter.

year of Jupiter differs in a much more striking
than that of Mars from our terrestrial year.
sts of nearly twelve such years as ours, so that
iod corresponding to one of our seasons lasts
hree years, and a Jovian month is nearly equal
of our terrestrial years. He has, however, no
in our sense of the word, since his equator is
l but little more than three degrees to his orbit.
perpetual spring reigns all over his surface.

before we proceed to form a high opinion of
net's condition under the influence of this per-
spring, let us distinctly understand what the
nean. The word 'spring' has a genial sound to
es, because we associate it with that which is
nly the pleasantest portion of our year; but it
possible that the perpetual spring reigning over
, though doubtless well adapted to the wants
nhabitants, leads to a state of things such as we
not find altogether so agreeable.

as been said that 'as the rays of the sun fall
dicularly on the body of the planet, and always
e to do so, the heat must be as nearly as pos-
qual at all times of the year, a perennial

om the sun is compensated for by this peculiar dis-
sition of his axis, and we are to admire the bene-
ence thus displayed, are we therefore to find male-
ence in the fact that Saturn, Uranus, and Neptune
ve been otherwise dealt with, though, being farther
om the sun, they have greater need than Jupiter of
me special arrangement of the sort? It seems safer
consider the consequences which flow from the ar-
ngement without any special reference to its purpose,
st, in our over-anxiety to recognise beneficence in the
eatment of one world, we should adopt a mode of
asoning which leads to the direct conclusion that
her worlds have been ill-treated.

The great peculiarity resulting from the arrange-
ent in question—the only peculiarity, in fact, of
hich we can speak with any confidence—consists in
is, that everywhere on Jupiter day and night are of
qual length. It is in this sense only that perpetual
pring—or perpetual autumn, if we please—reigns on
e giant planet. The different latitudes of Jupiter
ve climates differing quite as much as those found
different latitudes on our own earth. At the equa-
r the sun passes every day nearly to the point over-
ead. At the poles the sun seems to glide along the
orizon, rising in the east, passing round—always near
e horizon—towards the south, and thence to his
tting-place in the west. In intermediate latitudes
e sun passes to a southerly elevation, which is greater
less according as the place is nearer to or farther

d difference between the sub-equatorial and the
lar regions in Jupiter, while between these re-
every intermediate climate is to be found.

ing to the rapidity of Jupiter's rotation, the
of the sun in the Jovian sky must be much
eadily discernible and measurable than that with
the sun seems to pass across our own heavens.
averses the whole semicircle, from the eastern
western horizon, in two minutes less than five
or about six degrees in ten minutes. This cor-
ls to a motion through a space equal to the sun's
er (as we see him) in fifty seconds, and must
dily discernible, even to the unaided vision of
ricolæ, unless their eyesight is much inferior to
The smallness of the sun, as seen from Jupiter,
elp to render the motion more perceptible. He
s to them an apparent diameter only equal to
ne-fifth of that with which we see him, so that
seconds he seems to pass over a space equal to
diameter.

other celestial bodies are affected with similar
as seen from Jupiter. Of course, those seen
e poles of his heavens seem relatively at rest.
these poles lies in the heart of the constellation
the other lies close by the Greater Magellanic
which must present a magnificent cynosure to
habitants of the southern hemisphere of the

quatorial groups are no other than our old friends he zodiacal constellations. As seen by the inhabitants f Jupiter, they rise with a perceptible but stately iotion above the eastern horizon, pass to their culination on the southern meridian, and so to their etting-place in the west—exhibiting the same splenours which the terrestrial astronomer delights to gaze pon, enhanced by the peculiar impressions of active ower suggested by visible and obvious motion.

.t may seem, at first sight, that the presence of the ovian satellites must tend to dim the splendour of the dereal heavens. Our own moon, despite the beautil passage[1] in which Homer has described the calm eauty of a moonlit night, certainly detracts largely om the magnificence of the star-groups; and as at mes there must be four moons visible above the orizon of the Jovians, it might seem that all but the righter stars would be quite obliterated. The first ioon must appear somewhat larger than our own; the ext has an apparent diameter rather more than half s large as that of our moon; the third (really the rgest) appears about as large as the second; and the ourth has an apparent diameter equal to about a uarter of our moon's. Thus, in all, they cover a ace on the sky more than half as large again as that hich our moon covers. But, in reality, they cannot

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[1] Homer must not be held responsible for Pope's amazing deription, which, strangely enough, has found an ardent admirer in

arly so marked an effect in dimming the lustre
tars. For it must not be forgotten that they
nly by reflecting the sun's light, and that he
ates them but faintly in comparison with the
: pours upon our own moon. In effect, sup-
their reflective capacities equal to the moon's,
ust appear less brilliant than she does, in the
on of about one to twenty-five; and, combining
ult with the above relation, it follows that even
could all be 'full' together, they could send to
ians but about one-sixteenth part of the light
ive from the full moon. But, as a matter of
ey cannot all be full together. The motions of
ner three are so related that, though there is
g to prevent them from being all visible toge-
et when so visible, one only can be full. The
may be full at the same time, or in fact may
ciated with the other three in any way, since its
s are not bound up with theirs as theirs are
e.

n now, however, we have not reached a full
e of the extent of the mistake which those
mers have made who speak of the splendour
which the satellites of Jupiter illuminate his
When at that part of their orbits where they
otherwise be full, the three inner moons are
eclipsed; and though the fourth, by reason of

its great distance,[1] sometimes escapes eclipse, yet more frequently it is obscured like the others. The two inner satellites are eclipsed for upwards of two hours, and as they occupy but a few hours in completing their circuit round the sky,[2] it will be seen how largely this relation detracts from their light-supplying powers.

We see, then, that those writers have been mistaken who allege that the great distance of Jupiter from the sun is compensated by the number of his moons, and the quantity of light they reflect towards him. So far is this from being the case that, under the most favourable circumstances, they can supply during the Jovian night but about one-twentieth part of the light with which the full moon illuminates our nocturnal skies. The poetical descriptions which imaginative writers have indulged in, respecting the splendour of the scene presented by these satellites, will not bear the dry light of numerical estimation. That the satellite-system of Jupiter subserves, or may hereafter subserve, important functions need not be questioned; but that we can recognise them as created for any special purpose may be assuredly denied.

Perhaps, if one were able to discuss with advantage the special purposes which this or that portion of the

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[1] Not on account of the inclination of its orbit being large, as has been asserted. The orbit of this satellite is, indeed, less inclined than the orbits of the others.

[2] Moving in a direction contrary to that due to the rotation of Jupiter, they of course remain longer above the horizon than the sun, or than the equatorial fixed stars.

rse is intended to subserve, it might be argued
the outer planets have greater need of moons
the inner, because, their year being longer, there
eater occasion for objects whose motions shall
as measures of time. The satellites of Jupiter
y, by their separate motions, convenient measures
e shorter time intervals; while, by their succes-
conjunctions, (i.) in pairs, (ii.) the three inner
her, and (iii.) the outer with pairs of the inner,
afford convenient measures of longer intervals.

ut let us turn from vague guesses such as these
e consideration of those facts which are actually
nted to our notice.

ecognising the existence of varied climatic rela-
in different parts of Jupiter, we have now to
ler the climate of the planet generally, to con-
late the position of this great orb in the solar
m, and to determine how far its great distance
the sun may be compensated by other relations.

here can be no doubt that the amount of heat
d by the sun on any portion of Jupiter's surface
d perpendicularly with respect to the heat-rays,
be very much less than the amount received
equal portion of our earth's surface similarly
ed. The direct heating effects of the sun must
ct, as already stated, be less on Jupiter than on
own earth, in the proportion of about one to

iency of heat. If we can demonstrate in any way at the mean temperature of the Jovian atmosphere equal to that of our own air, or even greater, yet the fference of the sun's direct heat involves a variety of nsequences which we cannot disregard.

We know, for instance, that it is principally the rect heat of the sun that causes the evaporation water from the surface of oceans, seas, lakes, and vers, and therefore all the important consequences hich flow from the presence of aqueous vapour in rge quantities in the earth's atmosphere. We can nceive the existence of vapours in the air which ght keep away from the earth's surface the greater rtion of the sun's heat, and yet, preventing the cape of the remainder by radiation into space, ght leave the general warmth of the air around us great as it is at present. But it cannot be doubted at such an arrangement would injuriously affect the hole economy of evaporation and its consequences, nds, rains, clouds, mist, with *their* consequences, so portant to terrestrial races.

And in like manner other effects accruing from the ect action of the solar rays might be considered.

It follows, then, that it is by no means sufficient to ow how the heat which falls upon Jupiter may be red up, through the action of some component of s atmosphere in preventing its radiation into space. is, indeed, of the utmost importance to know that en this is possible, because we are thus enabled to solate as some writers have imagined. In the g passage, Professor Tyndall has exhibited the by which this result may be brought about, inhabitants of the noblest planet in the solar placed somewhat higher in the scale of crea- n Whewell surmised. 'In these calculations,' arked, referring to Whewell's estimate of the eating power on Jupiter and the other exterior , 'the influence of an atmospheric envelope was ked, and this omission vitiated the entire argu- It is perfectly possible to find an atmosphere vould act the part of a *barb* to the solar rays, ing their entrance towards the planet, but pre- their withdrawal. For example, a layer of inches in thickness, and saturated with the of sulphuric ether, would offer very little re- to the passage of the ether rays, but I find would cut off fully thirty-five per cent. of the y radiation. It would require no inordinate ing of the layer of vapour to double this ab- ; and it is perfectly evident that with a pro- envelope of this kind, permitting the heat to ut preventing its escape, a comfortable tem- e might be obtained on the surface of our istant planet.' The difference between such ngement as this and the way in which the planets may be no higher than that of our own air, while yet the sun's direct rays continue wholly unbearable, so the outer planets may have a perfectly comfortable temperature, while yet that direct solar heat which exerts so many important influences on the earth must be supplied only in quantities which we should find wholly inadequate for our wants.

I am far from desiring to infer that Jupiter may not hereafter be uninhabited, or even that creatures then existing on his surface must necessarily differ wholly in their nature from any with which we are familiar. But I think that while, on the one hand, we must reject one of the chief arguments by which Whewell was led to people Jupiter with cartilaginous and glutinous creatures floating in boundless oceans, so, on the other, we cannot accept without question the argument by which an effort has been made to indicate the possibility of a close correspondence between Jupiter's climate and our earth's.

And here we are led to the most interesting and suggestive of all the relations exhibited by Jupiter, or rather to three closely associated relations which lead to views of a somewhat startling character.

In common with the other large planets lying outside the zone of the asteroids, Jupiter has a mean density falling very far short of the mean density of the earth or the other small planets which travel within that zone. According to the best estimates of his mass and apparent diameter, his mean density would seem to be rather less than one fourth of the

, or greater than the density of water by about rd. It is worthy of remark, in fact, that his is almost exactly the same as the sun's, and rably greater than that of the other three outer hitherto discovered.

ve were quite certain that the disc measured by ibits the real outline of the planet, or that his here is not of abnormal extent, and that his is solid throughout, it would follow that the nces composing Jupiter are either altogether nt from those forming our earth, or that they mbined in very different proportions. On the int we can form no opinion. On the first we e guided by the appearance of the planet.

is we are led to the second of the three relations nentioned—the appearance of well-marked but e belts on the planets, and of other indications ng the existence of an atmosphere of great

e belts of Jupiter are commonly arranged with a symmetry on either side of the great equatorial belt, but sometimes there is a rather marked t between the northern and southern halves planet. In colour the dark belts are usually—seen with suitable telescopic power [1]—of a copry, ruddy, or even purplish tint, while the inter- diate light bands vary from a pearly white in the uatorial belt, through yellowish-white in the middle itudes of both hemispheres, to a greyish or even uish tint at the poles. The picture of Jupiter which ms the frontispiece, while exhibiting many of the tures usually seen, is intended specially to illustrate ations presently to be dealt with.

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[1] at is required is not so much a high light-gathering as a

There is every reason to believe that these belts licate the existence of a very extensive vapour-laden nosphere. The dark belts must not be considered as e true cloud-belts, because it must be remembered at we look upon the reverse side of the skyscape esented during the day to the Jovians: so that where ey see densely compacted dark clouds, we see the ht which those clouds have intercepted; and, on the ner hand, where they see clear spaces, the light ich reaches them is not reflected to us without a nsiderable loss of brilliancy. Thus the dark belts of piter are those regions where—if at all—we see the e surface of the planet.

Now, viewing the belts in this light, have we any eans of judging from their aspect what is the extent the planet's atmosphere? So far as I know, the estion has never been considered, but it is well rthy of careful study.

It seems clear, in the first place, that if the bright lts really are cloud-belts, and the dark belts the surface

e planet, then on the edge of the planet's disc we
to see some irregularity of level—the cloud-belts
ting slightly beyond the real outline of the planet
he atmosphere have that enormous extent which
astronomers have supposed. Whether such an
rance has ever been looked for I do not know,
has certainly never yet been detected.

e are led to conclude, then, that either the atmo-
e of Jupiter is not sufficiently extensive to inter-
ppreciably with our measurement of the planet's
or else the dark belts belong but to a lower cloud-
not to the planet's real surface.

e have further evidence on this point in the ap-
nce of dark spots on the dusky belts. These spots
ever been described as black, though surely their
ring of that hue must be ascribed to the effect of
ast. Now these dark spots, which have been seen
ssini, Mädler, Schwabe, and others, may be re-
d as the real surface of the planet (unless they
g to a yet deeper cloud-layer), seen for a while
gh openings in the cloud-bed to which the dusky
belong. The reader will not fail to notice here
resemblance to what has been already mentioned
cting the sun-spots: and when we come to the
and most striking of the associated features I am
dealing with, it will be seen that there may be

the extent and constitution of the Jovian atmosphere, it is not very easy to determine. That they are dense clouds, hanging suspended above the dusky cloud-layer, must be admitted as highly probable, but it is open to question whether they have formed there in the same way that cirrus clouds are seen to form at a great elevation above a layer of cumulus clouds, or whether they indicate the action of volcanoes beneath the dusky layer, propelling enormous streams of vapour through the superincumbent cloud-beds.

The third point on which I have to dwell is the variability of the belt-system, under which head I include not only variations in shape and extent, but those much more significant changes of colour which have been recently discovered.

So far as is yet known, there is no recognisable law in the changes of shape exhibited by the belts of Jupiter —no periodicity or intelligible sequence. It may be suggested, in passing, that a systematic and persistent scrutiny of the planet might lead to the discovery of laws of this sort, which could not fail to indicate physical conclusions of the utmost importance. Nay, further, since we cannot doubt that the condition of the real surface of Jupiter is in some sort reflected, so to speak, in the aspect of his cloud-envelopes, it seems far from unlikely that a scrutiny of this sort might tell us where his oceans and continents, where his deserts, lakes, or rivers, are situated, even though no direct evidence of their existence might ever reward the observer. In these days, however, nine-tenths of

e who are fortunate enough to possess fine tele-
es prefer either to leave them idle, or to employ
powers in making observations, at great pains and
ır, which are not worth the paper on which they
ecorded. The few original observers we have are
tasked by the multitude of questions of interest
ented to their consideration; so that many subjects
quiry must perforce wait, either till their turn
es, or till those who have the means of studying
choose to turn their thoughts from the sterile sub-
they are now engaged upon.

So far, then, as inquiries have as yet been pushed,
hat can be asserted on the subject we are consider-
is, that the planet's belts vary greatly in form, ex-
, and general appearance. At one time the dusky
s cover a large proportion of the planet's disc, at
her they are singularly narrow. Now they are very
larly disposed, now they seem in some way under
action of disturbing forces of great intensity,
ing them to assume the most irregular figure. The
mpanying picture of the planet (fig. 1), as seen by
Browning with one of his own reflectors, indicates
ppearance not uncommonly seen, a dark streak
nding obliquely across the planet's equatorial re-
s. The number of belts is singularly variable.
etimes only one has been seen, at others there

completely, while a third had almost disappeared in the same short interval of time.

The storm-tossed aspect of the planet is well shown in the characteristic drawing by Mr. De la Rue, which forms the frontispiece.

But if we seem to recognise here the action of forces much more intense than those which influence the conditions of the earth's atmosphere, we have still more striking evidence to the same purpose in the changes of colour which have recently been detected in the great equatorial belt. This belt is usually of a pearly white tint, and has long been recognised as one of the most constant features of the planet's aspect. As the mean surface of this belt cannot be less than a fifth of the whole surface of the planet, it is clear that any

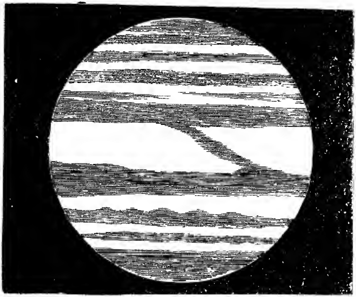

Fig. 1. The Planet Jupiter (Browning).

ges which may take place in its general aspect
t but be of the utmost significance. Now, during
utumn of 1869 and the spring of 1870, this belt
more strongly coloured than any part of the
t. Mr. Browning, observing Jupiter in the earlier
f the above-named interval, found the equatorial
of a greenish-yellow colour, which deepened in
er 1869 to a full ochreish yellow, and in January
had assumed an even darker tint, resembling
v ochre. On one occasion, and on one only, he
ted this tint in the first bright belt north of the
or. While thus exhibiting strongly marked and
ging colours, the equatorial belt had lost its right
called, *par excellence*, the bright belt of the
t, being considerably inferior in brilliancy to the
w bright belts north and south of it.

ther observers have also seen these colours. Mr.
, with a 6-inch Browning-With reflector, and Mr.
ley, with an 8½-inch telescope of the same con-
tion, have witnessed most of the changes of colour
described; and I myself, using Mr. Browning's
nch telescope, found the greenish-yellow tint of
quatorial belt in the autumn of 1869 altogether
stakable.

the phenomena here described we have a problem
interpretation is far from easy. Changes in the
, disposition, and extent of the dark belts

f Jupiter as the trades and counter-trades traverse
ie earth's atmosphere. But the equatorial zone is
upiter's belt of calms, resembling in this respect the
quatorial region, called by sailors the 'doldrums'; and
hough occasional storms might be expected to agitate
his region, yet processes of change continuing for
everal months in succession can evidently not be
tributed to any such cause. We are taught by the
rogress of recent research to regard the colour of
ie light derived from any source as a relation of the
ost instructive character; and changes of colour,
specially changes affecting so enormous a body as
upiter, and so extensive a proportion of his surface,
annot but be looked upon as highly significant. Sup-
osing we regard the ordinarily white light of the
quatorial belt as indicative of the existence of
normous masses of cloud, reflecting ordinary solar
ght to us, then we should have to regard the appear-
nce of any other colour over this region as an indica-
on that these cloud-masses had been, through some
nknown cause, either wholly or in part swept away.
ut—passing over the objection that this view leaves
ur difficulty unexplained—even if we assumed that in
his way a portion of the surface of Jupiter had been
rought into view, wholly or partially, why should this
urface not exhibit a constant appearance? We cannot
uppose changes affecting Jupiter's real surface are
aking place with sufficient rapidity to explain the
eries of strange colour-changes observed by Messrs.

r hand, we assume that a portion of the light ordi-
y received from the bright belt is inherent—that
hat the planet is, to some extent, self-luminous,
there remains the difficulty of explaining by what
eivable processes the equatorial regions are filled
a yellow light, so full and bright as to reach our
n from beyond four hundred millions of miles.

But I have spoken of the three relations last con-
red—the small density of Jupiter, his extensive
osphere, and the changes which take place in the
e and colour of his belts—as associated phenomena.
emains that I should endeavour to justify this
ement.

We know that Whewell, reasoning from the low
ific gravity of Jupiter, was led to the conclusion
either the substance of the planet is wholly watery
se a few cinders in the centre of Jupiter's globe
titute the only solid portion of his substance. It
hardly be said that the whole progress of modern
nomy is opposed to this view. We have seen
in the sun the same elements exist as in the earth;
n Mars, the only planet whose nature we have been
to examine satisfactorily, we find evidence of the
ence of the same forms of matter that we see
nd us. It cannot but be held as highly impro-
e that the earth is the only member of the planetary
em whose substance thus closely resembles that of

re really to learn from these circumstances, is that hroughout the solar system a general similarity of onstitution exists, the sun being, so to speak, the ype of the family over which he rules. Differences f *condition* we are compelled to recognise, since the un itself, though constituted of the same elements as he earth, is in so different a state, and has a mean ensity relatively so small; but we have no evidence ustifying us in believing that any important differences f constitution exist throughout the solar system.

. Thus we are led to regard the singularly small ensity of Jupiter, and of the other planets outside the rbits of the asteroids, as due rather to some peculiarity n the condition of these orbs than to any such pecu-arity of structure as Whewell insisted on. It will e seen at once that Jupiter's extensive atmospheric nvelope, and the strange changes in the aspect of his elts, are circumstances which tend strikingly to confirm his impression. Let it be remembered that, supposing upiter's globe even to be wholly covered with water, et a sun twenty-five times further off than ours could ot by any possibility load the planet's atmosphere ith the enormous masses of vapour actually present n it. Let it be remembered, further, that the relatively uggish action of the sun upon Jupiter could not by ny possibility give rise to atmospheric disturbances so remendous as those which are indicated by the rapid hanges of figure of his cloud-bands.[1] When to this d the relative minuteness of the seasonal changes piter, we see at once that unless some other than solar action were at work, Jupiter's atnere ought to be very much calmer than the s.

here is yet another circumstance in the condition piter's belts which opposes itself in a very striking ght even say altogether convincing) manner t the belief that the belts of Jupiter are raised e sun's action. The tropical cloud-zone of the not only varies in position with the seasons— g considerably to the north of the equator in er, and considerably to the south in winter, but in truth a region of midday cloudiness, not of l cloudiness. As respects the former relation n learn little from Jupiter's aspect, because his ation is so small that the annual sway of his orial zone would be exceedingly small also, and well remain undetected. But as the belts of n must be regarded as well as those of Jupiter in g an opinion on the subject we are upon, and as ief bright belt of Saturn, despite the considerable

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ar to our own), yet atmospheric disturbances (due chiefly, now, to these two forms, of action) could not possibly be so even as on our own earth, since corresponding latitudes on (that is, regions where corresponding effects would be nced) are separated by distances so very much greater. It inclination of the planet's equator, remains throughout the year persistently equatorial, we may conclude that the Saturnian belts—and presumably, therefore, those of Jupiter also—are not sun-raised. To suppose that the sun would have power to raise belts of clouds, and yet that he would not have power to cause them to follow him as he passes far to the north and to the south of the Saturnian equator in the long Saturnian year of twenty-nine terrestrial years, seems unreasonable in the extreme. It is, however, from the second relation that the most direct argument is derived in the case of Jupiter. In the latitude of the terrestrial cloud-zone the sun rises in a clear sky; shortly before noon the sky has become overcast, and storms of rain and thunder continue until the afternoon is well advanced, after which the clouds pass away and the sun sets—as he had risen—in a clear sky. Now we know quite certainly that nothing of this sort happens in the case of Jupiter; for we see his equatorial bright belt stretching right athwart his disc;—that is, not only covering the centre of the disc, where it is noon on the planet, but extending to the edge on either side, or to places where the sun is rising and setting. There seems no escape from the conclusion that the belt is wholly different in character from our terrestrial cloud-belt—that, in fact, it is not sun-raised at all.

It seems to me that these considerations point with tolerable clearness to the conclusion that, within the orb which presents so glorious an aspect upon our skies, processes of disturbance must be at work wholly

ent from any taking place on our own earth. That
nous atmospheric envelope is loaded with vapor-
nasses by some influence exerted from beneath
vel. Those disturbances which take place so
ently and so rapidly are signs of the action
rces enormously exceeding those which the
an by any possibility exert upon so distant a
. And if analogy is to be our guide, and we
o judge of the condition of Jupiter according
at we know or guess of the past condition of the
and the present condition of the sun, we seem
the conclusion that Jupiter is still a glowing
fluid probably throughout, still bubbling and
ing with the intensity of the primæval fires,
ng up continually enormous masses of cloud to
thered into bands under the influence of the swift
on of the giant planet. No otherwise, as it
s to me, can one explain the intense vitality, if I
use the expression, of a planet circumstanced as
er is. No otherwise can one understand whence
tmosphere is loaded with vapour-masses whose
nts must exceed, on a moderate compntation, all
ceans on the surface of this earth. When we see
s so enormous swayed by influences of such
y that intermediate belts thousands of miles in
are closed up in a single hour,[1] when we recog-

e the tremendous character of the motions which
m beyond four hundred millions of miles are dis-
ctly cognisable by our telescopes, we see that we
ve no ordinary phenomena to deal with, and that the
eory we adopt for their explanation cannot be other-
se than striking and surprising.

If the view which I have here put forward—or
her, the view to which I have been led by a careful
nsideration of the phenomena which Jupiter presents
our contemplation—be indeed correct, we must of
urse dismiss the idea that the giant planet is at pre-
t a fit abode for living creatures. Yet need we not
n from his system with the thought that here at least
r hopes of recognising other worlds have been dis-
pointed. If Jupiter be still in a sense a sun, not in-
ed resplendent like the great centre of the planetary
heme, but still a source of heat, is there not excellent
son for believing that the system which circles around
n consists of four worlds where life—even such forms
life as we are familiar with—may still exist? Those
r orbs, which our telescopes reveal to us as tiny
nts of light, are in reality globes which may be
npared with the four worlds that circle nearest to
e sun. I have shown that they cannot subserve the
rpose which many astronomers have ascribed to them,
compensating Jupiter for the small amount of
ht he receives, even if they could be seen from any
nt of his cloud-encompassed surface. So that, even
opting the commonplace and superficial view that the

we have been able to ask (without any obvious r) what other purpose it *can* subserve, we still l to the belief that the satellites of Jupiter must e abode of life, since on this view, and on this nly, we find a *raison d'être* both for the planet r the system which circles round him.

here are no considerations which appear directly ed to the view that Jupiter is in a sense a It need hardly be said that I do not regard s being in the same condition as the central ary of the planetary system. If he is an incan- t body, the greater part of his light is veiled c cloud-envelopes which surround him. The clouds are, as we know, themselves luminous; of Jupiter are not so—a circumstance which tes that the heat of Jupiter is not sufficient porise those substances which are incandescent in the liquid state. The outer layer of clouds therefore, be regarded as for the most part us. We see *there*, in fact, the future oceans of er, if the hypothesis I am now dealing with be t.

hat Jupiter may supply an immense amount of to his satellites (on this view of his condition) is tly clear, since the amount of light he emits is lequate measure of the amount of obscure heat mitting to them. From the outermost satellite his apparent diameter exceeds that of the sun (as seen by us) some eightfold, and his apparent size, therefore, exceeds the sun's more than sixty-fold. From the innermost he is seen with a diameter nearly forty times that of the sun, and with an apparent area more than 1,400 times as large as his!

We have evidence, however, which renders it far from improbable that Jupiter may emit some small proportion of light. I have already referred to the singular excess of his brilliancy over that due to his size and his distance from the sun and from us. The estimates of Zollner, the eminent photometrician, serve to show, not indeed that Jupiter sends more light to us than he receives from the sun, but that he sends much more light than a planet of equal size, and, constituted like Mars, the moon, or the earth, could possibly reflect to us if placed where Jupiter is. Whereas Mars reflects but one-fourth of the light he receives, Jupiter reflects more than three-fifths. The moon sends less than a fifth; Saturn, Jupiter's brother giant, more than a half. The late Professor G. Bond, of America, actually calculated that Jupiter sends forth more light than he receives. Whether his observations or the more systematic observations of the German astronomer are accepted, we see that unless we adopt some such hypothesis as I have dealt with above, we must recognise a marked difference between the relative light-reflecting capacities of the two largest planets of the system, and those of Mars or the moon. In rom other researches of Dr. Zöllner's, it follows Jupiter does not shine in part by native light, his e must possess reflective powers nearly equal to of white paper. Now this would scarcely be le, even though under the telescope the planet's e were found to be uniformly white; but as we large proportion of it to be of a dull coppery we seem forced to admit that it cannot really an average reflective power nearly so great as alculated by Zöllner. It follows, as at least probable, that Jupiter shines in part by his ght; and this being admitted, we cannot but it as highly probable that the real globe of the must be intensely hot.

may seem, at first sight, that the apparent blackf the satellites' shadows, as seen on the disc of r, is wholly opposed to the view that any portion light is native. But as a matter of fact there orce at all in this consideration, or rather, whateight we may attach to the observed appearance satellites' shadows is in favour of the strange here put forward. For it has been a subject of among the most experienced observers, that a te in transit will occasionally appear as dark asdow, both seeming black. The blackness, then, apparent, and an effect of contrast. In reality, h observations as I have mentioned are to be rface on which they are projected is partially self- minous.

A stronger argument against the belief that Jupiter self-luminous lies in the fact that the satellites sappear in his shadow. It must be remembered, owever, that in any case we can assign but a small oportion of inherent light to Jupiter, and that his tellites would therefore, in any case, lose so large a oportion of their light when passing into his shadow at we might expect them to disappear, even under e closest telescopic scrutiny.

One of the most surprising phenomena ever wit- ssed by the telescopist seems to me to afford even ronger evidence than any yet adduced. I refer to e observation made by Admiral Smyth, that on one casion the second satellite of Jupiter, twelve minutes ter entering on the disc of the planet, was seen *out- de the limb*, 'where it remained four minutes, and en suddenly vanished.' Two other equally competent servers, Maclear and Pearson, witnessed the same enomenon. 'Here,' says Webb, 'explanation is set defiance.' But it is precisely where explanation ems set at defiance that we have reason to be most peful of gaining instruction. The observation is y startling, it is true ; and the explanation may be cted to be also surprising. But I think it is not to seek. The satellite cannot have retraced its urse; Jupiter cannot have shifted his place: our ad of more difficult. A change in Jupiter's cloud- atmosphere, corresponding to that which I shall ntly have to exhibit as explaining Saturn's oc- ial assumption of the square-shouldered aspect, bviously account for the phenomenon. It is well n that the acute observer Schröter occasionally cted an apparent flattening of portions of Jupiter's ne, but the suspicion had been regarded as eous. We find, however, in the observation now estion, effective confirmation of that long-doubted rvation of Schröter's. If we consider the matter ly, this observation, made simultaneously by h, Maclear, and Pearson, renders that view all ertain which hitherto I have presented only as a y probable hypothesis.

lthough I have already far exceeded the limits I proposed to myself for the consideration of this planet, it is with regret that I take leave of him ss onward to the outermost bounds of the solar m. I would fain dwell even longer than I have subject of contemplation at once so interesting o instructive. Jupiter, the centre of a noble sys- of worlds, or Jupiter, himself a world inhabited by s as high perhaps in the scale of creation as he elf is in the scheme of the planets, is alike a ny subject of study. The more one dwells on the he presents the more one is impressed with ter feature is revealed beneath his scrutiny, may isregard the grand lesson which the heavens are ways teaching. But the astronomer, imbued with e sense of beauty and perfection which each fresh our of world-study instils more deeply into his soul, eads a nobler lesson in the skies. The music which eaches his ears may be fitful, but it is not 'as sweet ells jangled out of tune and harsh'; he may not aster its full meaning, though every note thrill rough his inmost soul; but even when its sounds are east distinct, they are full of mystical solemnity. In ne, the true astronomer may say with the Pythago-an, though in another sense,—

> There's not one orb which thou behold'st
> But in his motion like an angel sings,
> Still quiring to the young-eyed cherubim;
> But while this muddy vesture of decay
> Doth grossly close us in, we cannot hear it.

CHAPTER VI.

SATURN, THE RINGED WORLD.

piter by his commanding proportions affords a e argument against the view that our tiny earth only real world in the solar system, Saturn sup- n argument of scarcely inferior strength in the arly complex character of the scheme of which he centre. No one can contemplate this glorious , as shown by a telescope of adequate power, t being impressed by the conviction that he is g at a world altogether more important in the e of creation than the globe on which we live. er he recognises in the present condition of the the result of the action of laws which have for eriods reigned through the universe, or whether fers the view that Saturn and his system are seen s they were fashioned at the beginning by an hty creative hand, he is alike amazed at the exity of structure exhibited in the scene on which He may not be able, indeed, to roblem, be led to erroneous conceptions; but that the reat planet speaks of life, past, present, or to come, e cannot gravely question.[1]

In volume and mass Saturn is inferior to Jupiter. upiter is 1,230 times, Saturn not quite 700 times, as rge as the earth; and while Jupiter outweighs her 00 times, Saturn is scarcely 90 times as heavy as she . Still Saturn is sufficiently large and massive to warf our earth to insignificance; and even Uranus nd Neptune, though belonging to the family of the ajor planets, and giants compared with the earth, fall elow Saturn far more than he does below Jupiter.

Like Jupiter, Saturn rotates very rapidly on his xis, the length of his day being about $10\frac{1}{2}$ of our ours. The materials of which Saturn is composed ave a mean density not much greater than half that f Jupiter, or less than three-fourths of the mean ensity of water. In fact, Saturn's mean density is pecifically less than that of any known planet. It eems not impossible that we have in this relation some dication of the true cause of that complexity of detail hich the Saturnian system exhibits.

The equator of Saturn is inclined about $28\frac{1}{5}$ degrees o the plane in which the planet moves, so that his easons (so far as they depend on this circumstance y resemble in character those of the planet Mars. ccupies about $29\frac{1}{2}$ years in circling once round ın ; this, therefore, is the length of the Saturnian His distance from the sun is nearly twice that piter, and nearly ten times that of the earth ; so he amount of light and heat which any portion of ırface receives from the sun is about $\frac{1}{91}$ part of received by a similar portion of the earth's surface. rbit being somewhat eccentric, however, there onsiderable variation in this respect during the e of a Saturnian year, insomuch that when he is st to the sun he receives more light than when in ion, in the proportion of about 5 to 4.

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[1] I know nothing better calculated to lead men to choose as- ronomy as their favourite subject of study than the contemplatio f the Saturnian system. I can well remember the sensations ith which I saw the ringed planet for the first time. I look on

lost of the relations which have to be considered scussing the habitability of Saturn have been dy dealt with (under very similar conditions) in ng of other planets; so that I propose to touch em very lightly, in order to come more quickly ose circumstances which distinguish Saturn spe- among the other members of the solar system.

ravity at his equator is almost exactly equal to ty at the earth's surface. Near the poles there narked increase in the action of Saturnian gravity, nuch that a body weighing 10 pounds at his equa- ould weigh about 12 pounds at either pole. There thing, however, in this peculiarity which need be ally dwelt upon.

been considered in the case of Jupiter. We may conclude with some confidence that these relations are quite sufficient to render Saturn wholly uninhabitable by such creatures as exist upon the earth; but there seems no reason for supposing that (so far as these relations alone are concerned) the planet may not be the abode of living beings as high in the scale of creation as any which live upon our globe.

Thus viewing Saturn, we cannot regard even the exceptional effects produced by his ring-system as of themselves sufficient to banish life from his surface. These effects are not without interest, however, and as they have been made the subject of some discussion, I think it well to make a few remarks upon them.

I apprehend that when Sir John Herschel said that the rings occasion an eclipse of nearly fifteen years in duration, first to the northern and then to the southern hemisphere of the planet, he meant simply that during an interval of such length a large portion of either hemisphere was in shadow. He knew perfectly well that long after the edge of the ring has been turned directly towards the sun, a very large portion of the hemisphere over which the ring's shadow proceeds to sweep remains illuminated. It had always seemed to me, therefore, altogether a mistake on the part of Dr. Lardner to interpret Herschel's words as though implying that a whole hemisphere of the planet is eclipsed for fifteen years in succession.

So misinterpreting the expression used by Sir John

rschel, Dr. Lardner, in his desire to show that no
h relation existed, was led into real mistakes such
a sounder mathematician would not have made.
examined the relations presented by the ring in
uasi-mathematical but inexact manner, and came
the following conclusion—'that by the apparent
tions of the heavens produced by the diurnal rota-
n of Saturn, the celestial objects, including the sun
l the eight satellites, are not carried parallel to the
ges of the rings; that they are moved so as to pass
ernately from side to side of these edges; that, in
neral, such objects as pass under the rings are only
ulted by them for short intervals before and
er their meridional culmination; that although,
der some rare and exceptional circumstances and
ditions, certain objects—the sun being among the
nber—are occulted from rising to setting, the en-
ance of these phenomena is not such as has been
posed, and the places of their occurrence are far
re limited.' All these statements are more or less
orrect, and most of them are the direct reverse of
truth. The seven inner satellites of Saturn stand
an altogether different relation with respect to the
gs from all other celestial objects, since they travel
he same plane and in circles concentric with the
lines of the rings: they can no more be occulted
the rings, therefore, than an outer ring can be

ore common case (considering the whole planet) is r the sun to be eclipsed (if at all) throughout the nole of the Saturnian day; and a very common case, ft altogether unnoticed by Dr. Lardner, is that the n is occulted in the forenoon and afternoon, but free om eclipse in the middle of the day. Nor is it true at the places where the sun can be totally eclipsed roughout the day are limited to a relatively small rtion of the planet, since every part of the planet ience the rings are visible at all has the sun eclipsed . the rings throughout the whole day for a longer or orter succession of rotations. In the remaining or lar regions of the planet the sun is altogether absent r long intervals of time, for the same reason that he absent from the skies of our polar regions during a mparatively short interval. As for the endurance the total diurnal eclipses, it is only necessary to mark that in the Saturnian latitude corresponding to at of London or Paris the sun is totally eclipsed for ore than five years in succession, while in the latide corresponding to that of Madrid he is totally lipsed for nearly seven years in succession. This ffices to show that an arrangement which the inbitants of earth would find wholly unendurable preils over a very large proportion of Saturn's surface.[1]

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[1] The views here expressed as to the effects of the Saturnian gs are founded on exact mathematical calculation, of which the ments are given in my treatise on Saturn. The problem is not

t if we consider the matter rightly, we shall see his, after all, need not surprise us, since there is y in the enormous distance of Saturn from the e amplest reason for believing that he cannot abited by such creatures as exist upon the earth.* ı vain that by conceiving him to be surrounded dense atmosphere we assign to him a mean e as warm as that of the earth. The want of solar heat still remains, and must be regarded atal objection to the habitability of Saturn by resembling those with which we are familiar.

the case of Saturn as in the case of Jupiter, the ion of satellites and of the rings which form rious an object to the astronomer on earth is ther inadequate to increase the supply of light ed by the Saturnians to any such extent as has imagined. Those well-meaning persons who on their own interpretation of Deity's designs ngularly successful in overlooking very obvious lties. If the design of the rings, for instance, were to compensate the Saturnians for the small t of light which they receive from the sun, it surely follow that there was a want of wisdom selection of an arrangement by which more light t away from Saturn than the rings can possibly

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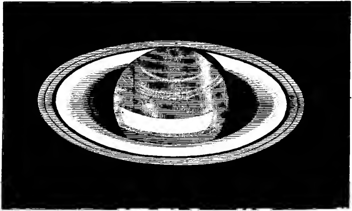
anner. I could not feel any doubt as to the accuracy of flect to him. And, further, during the very season hen the extra light derived from the rings is most quired by the planet, that is, during the long nights the Saturnian winter, they exhibit a dark band upon ie heavens, concealing whole constellations from the ew of the Saturnian people. As far as the satellites e concerned there is no corresponding difficulty. hey undoubtedly reflect the sun's light to Saturn. id if there really are intelligent beings on the planet, ie satellites must undoubtedly present an interesting ectacle, especially when a large number of the moons e nearly full. But a little consideration will show iat even though all the satellites were full at the same me, the quantity of light they could send back to ieir primary would be wholly inadequate to comensate for the planet's great distance from the sun. ccording to the best estimates of their magnitude, the ght satellites, taken in their order from their planet, ver spaces on the Saturnian heavens which bear to ie space covered by our moon the respective proporons of about 2, 1, $1\frac{1}{4}$, $\frac{3}{4}$, $\frac{5}{8}$, $\frac{1}{3}$, $\frac{1}{100}$, $\frac{1}{40}$. In all, then, iey cover an area about six times that of our moon; id as, owing to their great distance from the sun, they e illumined by only $\frac{1}{100}$th of the light which illuinates our moon, they could only send back to the anet, if it were possible for them to be all full gether, about $\frac{1}{16}$th part of the light we receive from ie full moon. It will be remembered that the light o our moon's. We seem forced to the conclusion he satellites were not intended to subserve any such n as has been imagined. Here, as in many other , the scheme of creation is not so obvious to n reasoning as some have complacently supposed.

ut we have now to consider peculiarities which est that Saturn's globe has not yet reached a con- fitting it to be the abode of living creatures. peculiarities resemble in great part those which been already noticed in the case of Jupiter, but ain most remarkable phenomenon belongs to the d planet alone.

he belts of Saturn resemble those of Jupiter in general shape (see the accompanying Plate) and n their colour. The dark belts near the equator a faint brown or ruddy tinge, those near the pole or greenish grey, while the bright belts are ish—the equatorial belt being the brightest of d almost white. The poles are commonly dusky, ven sombre in hue.

he belts change in aspect much as those of Jupiter been observed to do; and whether we regard the e as due to the bodily transference of the belts of or to the precipitation of their material in the of rain (while, elsewhere, invisible vapours are nsed into clouds), we are compelled to recognise tion of forces altogether exceeding those which



THE PLANET SATURN.

ually received by the planet than is observed in
case of Mars or the moon, and so nearly ap-
aches the proportion noticed in the case of Jupiter
o lead to the same inference—namely, that a portion
Saturn's light is emitted from the body of the
net.

In these respects, and also in the small density of the
net, we seem to recognise evidence which points to
urn as probably a heat-sun (if not to any very note-
thy extent a light-sun) to the satellites which circle
und him, and not himself the abode of living crea-
es. Without dwelling further on evidence already
ly considered in the case of Jupiter, I turn to one
the most striking facts in the whole range of obser-
ional astronomy, as supplying at once new evidence
pecting the condition of Saturn, and strengthening
evidence adduced respecting Jupiter.

If it can be shown that Saturn's globe is subject to
nges of figure perceptible even across the enormous
which separates him from the earth, it will at once
admitted that he can hardly be regarded as a globe
veniently habitable. Now I have very little hesi-
ion in saying that evidence of the most conclusive
d exists in favour of this strange mobility of figure.
will presently be seen that it is with the observa-
ns of no mere amateur astronomers that I have to
l in endeavouring to establish as a fact that which
commonly been spoken of as an illusion—the

t was in April 1805 that Sir William Herschel
called attention to this peculiarity. The planet,
h had always presented to him an elliptical figure,
ited a strangely distorted aspect. A well-marked
ning at the equator, accompanied by an equally
marked flattening at the poles, gave the planet's
an oblong figure (with rounded angles), the
st diameters having their extremities in Saturnian
de 48° 20′—so exactly was the great astronomer
o indicate the nature of the deformity, owing to
ll-marked character.

hat view shall we form respecting an observation
remarkable a nature? Was the peculiarity
to telescopic distortion? Herschel observed it
several instruments, some seven, some ten, one
y, and one forty feet in length. Was the phe-
non due to atmospheric disturbances? Such dis-
nces could not account for a persistent impression,
ver well they might explain the momentary as-
tion of the square-shouldered aspect by the ringed
t. Besides, Jupiter presented no such appear-
Was the appearance an optical illusion, due to
osition of the ring—then slightly open? If so,
lanet should always exhibit the square-shouldered
when his rings are open to that particular ex-
and this is not the case. Besides, we ought to

tremendous a nature as to upheave whole zones of his urface five or six hundred miles above their ordinary evel? Truly the conclusion is one to be avoided, if we can by any possibility find a less startling explanaion of the matter.

Yet where are we to look for such an explanation? Was Sir William Herschel simply deceived? I have lready considered the general question of illusion, but he reader might entertain the explanation as coneivable that Herschel had for a while lost the cumen which distinguished him—that illness, for exmple, might have rendered his observations inexact. But we have abundant evidence that the great astroomer was in the full possession of all his wonderful owers as an observer during the month of April 805; we know further that, by careful measurements, e rigidly excluded all possibility of illusion affecting is judgment.

It would be more satisfactory, doubtless, to the eader, however, to learn that other observers had oticed similar peculiarities, or peculiarities which, if ot similar, were at least such as to prepare us to onsider the globe of Saturn liable to remarkable hanges of figure. Fortunately many such observaions have been recorded. I take the following from one of a lengthy series of papers on Saturn by Mr. Webb, in the 'Intellectual Observer' for 1866.

On August 5, 1803, Schröter found Saturn not pergure described by Sir William Herschel, and with two different achromatics. At this time ng must have appeared too narrow to account for ppearance as due to illusion. On one occasion eorge Airy had a similar view of Saturn. marks, also, that a person unacquainted with hel's observation remarked spontaneously on the ed equator of the planet. On another occasion, Airy noticed the exact reverse, the planet seeming ed, instead of upheaved, in latitude 45°. In ry 1855, Coolidge, using the splendid refractor Cambridge (U.S.) Observatory, noticed that the st diameter of the globe seemed inclined about the equatorial diameter; but on the 9th the rial diameter seemed the greatest; while on mber 6 he says: 'I cannot persuade myself that n optical illusion which makes the maximum dia- of the ball intersect the limb half-way between rthern edge of the equatorial belt and the inner of the inner bright ring.' All this time the were nearly at their greatest opening, so that lusion should have been of an opposite character t observed when the rings were nearly closed. e report of the Greenwich Observatory for 61 it is stated that 'Saturn has *sometimes* ap- l to exhibit the square-shouldered aspect.' The nt observers Bond, father and son, have noticed

1848, when the ring was turned edgewise towards On the other hand, the same observers noticed t in 1855–57, when the ring was most widely ened, the polar region did not always seem projected thest on the outer ring in a symmetrical manner, t four times on the left of the pole, once on the ht, and once only exactly opposite the pole. 'The line of this region, also, occasionally appeared irrelarly flattened and distorted,' an appearance not isfactorily explained by the juxtaposition of the k shadow of the planet on the ring.

Now there can be no doubt whatever that the net Saturn is not ordinarily distorted. In 1832, ring the disappearance of the ring, Bessel carefully termined the figure of the planet's disc, and Main 1848 (when the ring was again turned edgewise vards us) made similar measurements. Each of se trustworthy authorities came to the conclusion at the disc of Saturn did not, at the seasons when ey respectively measured it, exhibit any distortion figure such as Herschel had described.

We seem almost compelled, therefore, to accept the nclusion that the planet Saturn is subject to the luence of forces which either upheave portions of its rface from time to time, or cause vast masses of ud to rise to an enormous height above the mean vel of Saturn's cloud-envelope. Whichever view we opt, we cannot fail to recognise the fact that an inse heat must in all probability prevail in the great

must emit a brilliant light, though the cloud-
surrounding him may prevent us from recog-
more than a minute proportion of his luminosity.
t, according to this view, Saturn and Jupiter,
the sun, whose real substance emits a less intense
than the cloud photosphere surrounding him,
have nuclei—solid or liquid—shining with an
ther more brilliant light than the cloud-envelopes
se planets seem actually to emit.

hy Saturn, rather than Jupiter, should exhibit
ime to time these mysterious changes of figure
dily explicable when we remember that the
in which the Jovian satellites move nearly coin-
with the orbital plane of their primary. There
lways results a close agreement between the
n which the satellites exert their greatest dis-
g influences and that most influenced by the
action. No such coincidence exists in the case
urn, whose satellites travel in a plane inclined
30 degrees to that in which their primary
s. We have seen, however, that evidence is not
g to prove that Jupiter is really liable to occa-
changes of figure, though not to such an extent
hange the general aspect of the planet.

hink the evidence in the case of Saturn favours,
st as strongly as that which has been adduced in

fully supplementing the small amount of heat which the sun supplies to the satellites circling around these orbs. Undoubtedly, if we are to judge according to the method which has been so often applied to such questions, if we are to ask ourselves according to what arrangement the central planets and the systems circling round them seem most reasonably interpreted, we should at once adopt some such conclusion. For, by taking Jupiter and Saturn to be strictly analogous to our own earth, and their satellites to be subsidiary bodies, resembling our moon in *this*, that they subserve at present no other purpose but to illuminate the nocturnal skies, and to sway the oceans of their primaries, we find ourselves perplexed by the consideration that a much simpler arrangement would have subserved these purposes much more completely. In the case of Saturn's satellites, indeed, it seems difficult to conceive that these bodies could have been intended to fulfil any such purposes, since the two outer ones could neither give any useful light to their primary, nor sway appreciably any oceans which may exist upon the planet.

These considerations lead me to believe that the two most important members of the planetary scheme must be left without inhabitants for the present, while in exchange I submit, to the contemplation of the curious, twelve small orbs, constituting two miniature world-systems. The condition of these worlds will be touched

CHAPTER VII.

RANUS AND NEPTUNE, THE ARCTIC PLANETS.

CUMSTANCE which is of great importance in ering the relations of the outer planets is apt to sight of, owing to the unsatisfactory manner in in nearly all books on astronomy the planetary are represented. To look at the series of equi- and concentric circles representing the orbits planets, who would suppose that in passing he orbit of Jupiter to that of Saturn a distance mes as great as that which separates our earth he sun has to be traversed? But the distance ting Uranus from Saturn is twice as great even tremendous gap, while Neptune travels as far d Uranus as Uranus beyond Saturn. Nine ed millions of miles in width is the enormous y which the path of Uranus is separated from the ringed planet on the inner side, and from distant Neptune on the outer; so that a line to the diameter of Jupiter's orbit would barely

We know so little of the physical aspect of Uranus and Neptune that it is extremely difficult to form any opinion as to their condition. The two planets resemble each other in size, each being far smaller than either of the giant orbs we have lately been considering. Uranus has a diameter of about 33,250 miles; Neptune is somewhat larger, his diameter having been estimated at 37,250 miles. The volume of Uranus is 74, the volume of Neptune 105 times that of the earth. Both planets exceed Saturn in density; for whereas Saturn's mean specific gravity is but $\frac{13}{100}$ths, that of Uranus is $\frac{17}{100}$ths, and that of Neptune $\frac{16}{100}$ths of the mean specific gravity of our globe. Thus each planet has a density nearly equal to that of water. The mass of Uranus exceeds the earth's about $12\frac{1}{2}$ times, while that of Neptune is some $16\frac{3}{4}$ times as great as the earth's. It will be seen, therefore, that though these two far-distant worlds are much less massive than Jupiter or Saturn, each of them outweighs many times the combined mass of the four planets which travel within the zone of asteroids. Yet gravity on the surface of these two orbs is but about three-fourths of terrestrial gravity.

The disc of the sun as seen from Uranus is less than that which we see, in the proportion of 1 to nearly 390, while the Neptunians have a sun only about $\frac{1}{900}$th of ours in apparent size; and in these proportions the solar light and heat received by these planets are respectively diminished. So small does the sun appear, in fact, that to eyes such as ours his orb would not

t a disc-like figure, but would appear like an
lingly brilliant day-star.

far we have found the circumstances of the two
s somewhat similar. But we have now to con-
a relation presented by Uranus, which is not
l in by Neptune. It may be remarked that we
so little about either planet that any very careful
eration of their habitability would be simply a
of labour. The evidence I am about to adduce,
er, in the case of Uranus, seems thoroughly to
e of the claim of this planet to be regarded as a
inhabited by creatures resembling those we are
nted with on earth; and as we cannot reasonably
se Neptune to be inhabited by such creatures
Uranus is not, we may very fairly regard the
on as disposed of for both planets, even though
lation dealt with is peculiar to Uranus.

ranus has a family of four satellites, Neptune has
ne satellite yet discovered. Now we know that in
se of Jupiter, as in that of Saturn, the position
plane near which the satellites travel is nearly
dent with the plane of the primary's equator.
fore, though no telescope has yet exhibited any
es on the discs of Uranus or Neptune which can
e us to determine the position of its equator, we
fely infer from the motion of the satellites how
uators of the planets are situated.

ortant for my present purpose, that they travel in a etrograde direction. The satellite of Neptune travels a path not inclined more than about 27° to the plane f the planet's path; but the motion of the satellite is etrograde. We conclude that the axis of Uranus lies ery nearly in the plane wherein the planet moves round the sun, and that the planet rotates in such a ay around this axis that the sun moves across the ranian skies from west to east, instead of from east west. The latter relation is of no great importance; e former, however, involves results which dispose at nce, and thoroughly, of any hopes we might entertain f discovering creatures in Uranus resembling those hich inhabit the earth.

The inclination of the plane of Uranus's equator to e path in which he travels being about 76°, it follows at the Uranian sun has a range of about 76° on either de of the celestial equator, during the long Uranian ear. Already, in considering the seasons of Venus, I ave dealt with a peculiarity of this sort; but in the ase of Uranus the effects are more serious. We have nly to consider what would be the result of so wide a nge of solar excursion north and south of the celestial quator in a latitude corresponding to that of London, see how importantly the climatic relations of a planet ke Uranus, occupying eighty-four years in circling nce round the sun, must be affected by such a pecu-arity. We know that in the latitude of London the un reaches at noon, in spring or autumn, an elevation mmer he passes the meridian 23½ degrees higher, in winter he passes the meridian 23½ degrees , or only 15 degrees above the horizon. But in ilar Uranian latitude, while the sun would reach ame meridian elevation in spring or autumn, he d in summer travel throughout the day in a small , 14 degrees only from the pole (raised of course egrees above the horizon), so that at noon he would ½ degrees, and at *nominal* midnight 37½ degrees e the northern horizon. And obviously, since the of the Uranians lasts 84 of our years, the continuance of the sun above the horizon would last for years.[1] So far there is nothing to render life ranus unpleasant, always supposing the small nt of light and heat supplied by the sun to be comted by some such atmospheric arrangements as cists have thought necessary for the convenience e more distant planets. But when we consider ature of the Uranian winter, we find the circumes such as no arrangements of the sort can be cond to alleviate. The winter path of the Uranian in a latitude corresponding to that of London, is s fully depressed below the horizon as the sum- path is raised above it. At midnight the sun

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[1] xact calculation applied to relations so uncertain as those question would be out of place. From a careful construc-

65½ degrees, at nominal noon he is 37½ degrees
low the southern horizon. And as with the summer
y, so with the winter night, years elapse before
her comes to an end. For upwards of 20 years, in a
itude corresponding to that of London, the Uranians
if there are any—never see the small Uranian sun.
iring all this long time, too, a sight even is denied
em of all parts of the solar system interior to the
bit of Uranus; though this deprivation cannot be
garded as very serious when it is remembered that
such eyesight as ours Saturn would barely be visible
m Uranus, even when most favourably situated,
ile Jupiter, always near the sun, would only be
casionally seen, shining with a light somewhat less
an a fiftieth of that which he reflects to us when in
position.

When we consider other latitudes, we find Uranus
provided for as respects his winter season. In
latitudes nearer the pole than the latitude just
nsidered, the Uranians have winters lasting from
enty years to upwards of forty. In latitudes nearer
e equator the winter night is shorter, but we must
proach quite close to the equator before we reach a
itude where the winter night lasts less than a year
so. Over a belt extending about 14 degrees on each
e of the equator there is a perennial succession of
ys and nights never exceeding the full duration
the Uranian diurnal rotation. But we must not

uces here also a variety of seasonal changes which iould find altogether unendurable. From a sun y rising above the horizon in winter, to a sun 1 rises vertically overhead twice in the course of Jranian summer, is a change which hardly accords our views of what is desirable in the progress of easons. At the equator itself there are in reality summers, occurring at the period of the sun's ng the celestial equator. Here for many years her the sun passes day after day to a point nearly iead. But then comes the long winter, in the of which the sun rises barely 14 degrees above northern or southern horizon. By whatever gement we render the long Uranian winters in part of the planet endurable, we render the heat s long summers unbearable; and *vice versâ*, if conceive of atmospheric relations which would er his summers pleasing, we have caused his ers to be so intensely cold that no creatures we familiar with could endure the prolonged and r frosts, contrasting so distressingly with the ined geniality of his summer weather.

f Uranus be inhabited at all, then, it must be by ures constituted in a very different manner from with which we are acquainted. To such creatures, ny among them be gifted with intelligence, the though not adorned with planets, must not f motion which we recognise in passing from the quatorial to polar constellations, would lead to a ertain complexity in celestial charts and globes, which ould invite us to the conclusion that the Uranians aust be capital mathematicians. Then there are ertain astronomical subjects of study to which their aathematical powers may be devoted perhaps more iccessfully than those of our astronomers. For example, the wide sweep of the planet's orbit would nable the Uranians to recognise a displacement of the ars in the course of the long Uranian year. The ar Alpha Centauri, which only exhibits to the terestrial observer an annual parallax of one second, ould exhibit to the observer on Uranus a displaceient of about the third part of a minute. Other stars ould be affected in like proportion, and perhaps the ranians may thus be enabled to form some conception f that relation which hitherto has proved too baffling problem to our astronomers—the actual configuraon of the nearer parts of the sidereal system. The eptunians would of course be even more favourably rcumstanced.

One difficulty presents itself, however, in thus condering the prospects of the Uranian and Neptunian stronomers. The enormous length of the year of ach planet requires that either the astronomers in ranus and Neptune should be very long-lived, or aat they should be very enthusiastic in the cause r earth. An Uranian who made one set of ations to determine stellar parallax when he was, venty-five years old, would have to wait till he early reached the threescore years and ten (not ps allotted as the span of Uranian life) before he make the corresponding set, by comparing which he former, stellar parallax was to be determined. ptune life must be prolonged over the century s the study of observational astronomy commence the babyhood of the Neptunians), in order that plete set of observations for determining stellar x should be carried out. One cannot but con- hat a certain sluggishness would mark the pro- f astronomy in these far-off worlds under such stances. In fact, the mere consideration that a constellation has passed away from the noc- skies of Uranus or Neptune, 30 or 40 years in se and 70 or 80 in the other must pass before onstellation again becomes favourably visible, ts characteristics of astronomical observation her different from those we are familiar with.

miral Smyth suggests that these distant planets be convenient outposts for watching the ap- or recession of comets; but I venture to point at the inhabitants of the earth are on the whole favourably situated in this respect. Every comet which approaches tolerably near to the om Uranus or Neptune, since to be visible a comet ust approach the sun or recede from him along a urse passing tolerably near to the particular position either planet at the time; and the changes in the se of any individual comet would be enormously ainst such a contingency.

With eyesight such as ours the Uranians would stinctly see Neptune when in opposition, but the eptunians would be wholly unable to see Uranus, or deed any known planet of the solar system.

Perhaps, though we have very little evidence on e point, it will be thought more reasonable to suppose that Uranus and Neptune are suns to their respective systems of satellites, than to imagine that ese two drearily circumstanced planets are themselves inhabited. Their satellites cannot possibly mpensate to any noteworthy extent for the small nount of solar light or heat which reaches their primaries. On the other hand, it is not difficult to conive that the planets may afford an important supply heat (at any rate) to their dependent orbs. Cerinly, so far as the evidence we have extends, Uranus d Neptune resemble Saturn and Jupiter too closely t to warrant the application of any arguments deced from the appearance of the two giant planets to e case of their inferior but still gigantic brethren.

Viewing the matter thus, we seem led to the conusion that the planets which lie outside the zone of roids are distinguished from those within that belt outes of size, density, rapidity of rotation, and the lexity of systems circling round them, but in this important and more interesting circumstance, they and their dependent orbs are real miniatures e solar system. Four suns they would seem to ot indeed suns resplendent like the primary sun l which they travel, yet giving out perhaps no nificant supply of light; not heated to incandence as he is, but still supplying an amount of proportionately far greater than the quantity of they give forth: in fine, not, as he is to the inner ts, the sole source whence all supplies of force lerived, but adding their influence to his in a ty of complicated but doubtless well-ordered com ions, in such sort that the small worlds which around them are provided with all that is necesfor the well-being of their inhabitants.

CHAPTER VIII.

THE MOON AND OTHER SATELLITES.

ALTHOUGH the moon cannot be regarded as at present he abode of any forms of life, such as we are familiar with on earth, there are many reasons for studying in a work on other worlds the various relations she presents o us. In the first place, she subserves various useful purposes in the economy of our own earth; then there are circumstances in her appearance which suggest hat at one time there may have been life upon her urface; and lastly, she affords us the only information we have concerning the probable relations presented by the noble systems of moons which circle around Jupiter and the other planets outside the zone of asteroids.

With regard to the present habitability of the moon, it may be remarked that we are not justified in sserting positively that no life exists upon her surface. Life has been found under conditions so strange—we have been so often mistaken in assuming that *here* ertainly, or *there*, no living creatures can possibly xist—that it would be rash indeed to dogmatise repecting the state of the moon in this respect.

ly different in character from those we have rto had to consider. We no longer have to with various degrees of heat and cold, of at-heric rarity or density, and the like, but with ions which do not in the slightest degree resemble e we are familiar with on earth.

n the first place, the moon has no appreciable at-here. We have long known this quite certainly, use we see that when stars are occulted by the n they disappear instantly, whereas we know this d not be the case had the moon an atmosphere ppreciable extent. But if any doubt could have ined, the evidence of the spectroscope in Mr. gins's hands would have sufficed to remove it. has never been able to detect a sign of the ex-ce of any lunar atmosphere, though Mars and er, so much farther from us, have afforded dis- evidence respecting the atmospheres which sur-d them.

hen secondly, there are no seas or oceans on the . Were there any large tracts of water, the endous heat to which the moon is subjected during ourse of the long lunar day (lasting a fortnight r time) would certainly cause enormous quantities ter to evaporate; and not only would the effects is process be distinctly recognisable in the tele-, but the spectroscope would exhibit in an un-

ion of the moon's axis to the orbit in which she travels
ound the sun is nearly 89°, and with this inclination
here can be no appreciable seasonal changes.

Fourthly, the enormous length of the lunar day is
ltogether opposed to our conceptions of what is suit-
ble for animal or vegetable life. The lunar day lasts
bout a fortnight, and the lunar night is, of course,
qually long. Were this all, the inconvenience of
he arrangement would not be endurable by beings like
urselves. But far more serious consequences must
esult from the combination of the arrangement with
he want of an atmosphere; for whereas during the
unar day the surface of the moon is exposed to
n inconceivably intense direct heat, undoubtedly
ufficient to heat that surface far above the boiling
oint, during the lunar night the heat is radiated
apidly away into space (no atmosphere checking the
rocess), and an intensity of cold must prevail of which
e can form but imperfect conceptions.[1]

The mere fact that our earth is always invisible from

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[1] The moon's physical habitudes are in fact so very different
om those of the earth that one cannot read without astonishment
e following passage in which Sir W. Herschel pleads for the
oon's habitability. 'Its situation, with respect to the sun,' he
ys, 'is much like that of the earth, and by a rotation on its axis
enjoys an agreeable variety of seasons (!) and of day and night.
o the moon, our globe will appear to be a very capital satellite,
ndergoing the same regular changes of illumination as the moon
oes to the earth. The sun, the planets, and the starry constella-
ons of the heavens will rise and set there as they do here, and
avy bodies will fall on the moon as they do on the earth. *There
ems only to be wanting, in order to complete the analogy, that it
ould be inhabited like the earth.*' The evidence, however, seems to

ree-sevenths of the moon's surface is one which
oints very strongly to the conclusion that the present
ndition of the moon is not the one best calculated to
eet the wants of living creatures on her surface. In
ng-past ages, when her rotation had not yet been
rced into accordance with her revolution[1] (as at
esent), the earth must have subserved a variety of
ost important purposes. If water then existed on
e surface of the moon, the earth must have raised
dal waves in the lunar oceans. She must further have
flected enormous supplies of light and heat towards
r dependent orb, even if at that time she were not
secondary sun for the lunarians. She must have
avelled across the lunar skies as the moon travels
er ours, presenting a variety of interesting and beau-
ful phases, affording useful time-measures, and so
abling the travellers on the moon in those long-past
es to guide their course in safety over her oceans or
r deserts. But now she is invisible from a large

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[1] The researches of Adams into the peculiarity of the moon's
otion called her acceleration, suffice to show that under the in-
ence of the moon's attraction on our oceans, the earth's rotation
gradually diminishing; so that, though many millions of ages
st elapse first, she will one day so rotate as to keep always the
me face turned towards her satellite. We cannot doubt that it
s been by a process of this sort that the moon's rotation has been
ought to its present rate. In fact, independently of the evidence
orded by the earth's gradual loss of rotation, we cannot account
the moon's peculiarity of rotation without regarding it as due to
e earth's controlling influence. A perfectly homogeneous sphere,
rted on a direct line at the moon's distance, and with the same
locity, would travel without rotation on an orbit like the moon's,

of the moon's surface, and almost a fixture in
es even of those parts of the moon whence she
seen. Were there lunar oceans, she could raise
s in them. Were there a lunar atmosphere, she
hed no heat, to be garnered up, so to speak, by
mosphere, and to compensate, in some sort, for
g absence of the sun.

t have we evidence that at some far-distant
the moon was inhabited? Taking for our
ce the analogies which are available to us, can
lly conclude that once, in all probability, those
wastes were clothed with vegetation, those
solitudes the abode of life?

hen we contemplate with attention the lunar
, considering the indications it presents of past
es, we are led to inquire how the forces which
een so busily at work were expended. If
, studied thoughtfully, teaches us the lesson
ere is no form of force which is not the repre-
ve of some other pre-acting form of force, she
aches us that no form of force ever works with-
nerating other forces as its own energies are
led. The meteor which sweeps with planetary
y through space may be brought to rest upon
n, but the energy stored up in its motions is not
; the sun may expend the stores of force he
from meteoric impact, but not idly:[1] all

und us we see the fruits of solar energies, we feel em within ourselves, we exert them upon others. d therefore when we see on the moon signs that r surface was at one time upheaved by tremendous lcanic forces, we are led to the conclusion that tween the era when she was thus disturbed, and the esent time, when she seems absolutely quiescent, ere must have been a period when her energies were for sustaining various forms of life; though it does t follow, of course, that they were so employed. ere *has*, in this instance, been a process resembling haustion, though we know that the forms of force ich have passed away from the moon have not lly ceased to exist; but before the lunar forces re dissipated into space, they may have subserved e purpose of supporting life.

Associated, however, with this subject, there are

one, gives an account of one large portion of the stellar heat pplies, because we know that, small as the amount we receive y be, we must multiply that amount millions on millions of nes to get the total received by all the orbs in space from this rticular sun. But we know that a large portion of our sun's ht and heat must either fail to fall on any other orbs, or must gradually exhausted in its progress through space (for if lines m the sun in every direction encountered orbs, the sky ought to lighted up at all times with star-splendour—which is no other n sun-splendour). In either case we cannot tell what becomes the portion seemingly wasted; though in the latter case we may rm confidently that there is simply a change in the nature of energy. In both cases we know that the total of energy in the verse remains undiminished. There is, indeed, a seeming contradiction here; but it is not different in character from the seeming contradictions suggested by the consideration of infinite space

ns of a perplexing character, which invite our
consideration. If life ever existed on the moon,
st have possessed an atmosphere and seas. In-
ently, also, of our views on the subject of life
he moon, we are led by the revelations of the
scope respecting the solar system, to believe
l the bodies within that system are in a general
imilarly constituted; and if this be so, there
nce have been oceans and air upon the moon.
has become of the moon's atmospheric envelope.
the lunar oceans?

four several ways this question has been an-
. Some have thought that the oceans and air
een withdrawn into cavities within the moon's
ace. Others have imagined that the air and
may have passed away to the farther hemi-
of the moon. According to a third theory,
has carried off the lunar oceans and atmosphere.
astly, a fourth theory has been maintained,
ng to which the lunar air, and *à fortiori* the
seas, have been changed by intensity of cold
e solid form.

these theories, the first and last only seem
of consideration. We see so much of the
farther hemisphere during her librations that
st perforce reject the second, even if we had
ustworthy reason for believing so strange an
ment to be possible.[1] The third theory is

posed by all that modern astronomy teaches re- ecting the constitution of comets.

The theory that an atmosphere formerly surround- g the moon has passed with the lunar oceans into the terior of our satellite has been supported by physi- sts of considerable eminence. The relatively low ecific gravity of the moon (little more than half the rth's) suggests the possibility that cavities large ough to contain even all the waters of our own eans may exist within the moon. Nor does the fact at we can see no unmistakable signs of chasms tending deep into the moon's substance suffice to nder the theory untenable, or even improbable. It difficult to understand how the retreat of the waters ok place. Certainly it cannot have happened while e moon's volcanic forces were in vigorous action; et a period must undoubtedly have arrived when by tle and little the waters could retire within the oon's substance without being vaporised. From hat we know of volcanic action on the earth, the nar volcanoes must have drawn fresh supplies of ergy from the gradual influx of water; and one can us understand why the aspect of the moon indicates at up to the last moment, so to speak, of her exist-

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avity, on which the theory has been based, can be admitted as an tablished fact. Independently of this, however, the theory will t bear close examination. Anyone who will draw a cross section the moon (in a plane passing through the earth), and endeavour assign such a position to an atmosphere of moderate extent that en during the moon's extreme librations no signs of the atmoence as a world, the forces upheaving her crust were busily at work. We can thus see how it has come to pass that the moon's surface shows so few signs of the action of rain or running water.

The theory that the lunar oceans have become frozen, and that afterwards even the gases forming the lunar atmosphere have become solidified, was maintained by Buffon and Bailly in the last century, and has been supported by several astronomers in our own day. In some respects, the aspect of the moon (especially the absence of well-marked colours from her surface) seems to favour the theory. Nor need the excessive heat to which the moon's surface is exposed for weeks at a time, be considered a sufficient reason for rejecting it, because we have no means of judging how that heat would act where there is no atmosphere to prevent its immediate and entire reflection into space. We know that despite the intense heat which is poured upon the summits of the Himalayas, the snow there—though a portion may melt during the day—remains year after year and age after age undiminished; and on the summit of the Himalayas the atmosphere is dense and heavy compared with that which exists even in the lowest abysms of the lunar ravines. But the results which have been deduced from the application of Lord Rosse's three-feet mirror to the measurement of the lunar heat, compel us to abandon the belief in the existence of frozen oxygen or nitrogen on the moon's surface, since, according to those results, a large proportion of the oon's heat is radiant—in other words, the moon's surce has been actually raised to a high degree of heat by e solar rays. Most physicists look with considerable nfidence on the method by which, in the researches ade at Parsonstown, an attempt has been made to disnguish between the heat which the moon reflects and at which she radiates into space.

On the whole, therefore, the former theory seems have the strongest evidence in its favour, or rather e least decisive evidence against it.

In considering the systems of bodies which circle ound the outer planets, we are struck at once by veral marked circumstances of contrast between eir condition and that of our own moon.

In the first place, we have no satisfactory evidence at the satellites of Jupiter and Saturn turn always e same face towards their primary. It is true that r William Herschel was led by certain observations the satellites of Jupiter to conclude that this relaon holds in their case. But we have far stronger idence against such a view, in the fact that modern servers armed with telescopes of the most exquisite fining powers have not only been unable to confirm e relatively rough observations made by Herschel, but ve noticed peculiarities of appearance only explicle by the theory that the rotation of the satellites is ite independent of their motion of revolution around piter. Dawes, for instance, has observed that the rkings seen on the third satellite, when transiting

well-defined black spot on certain occasions,
others it has appeared quite bright on the
the planet. He once saw this satellite bright
ered on the disc of Jupiter, and about half an
er as a dark spot; while Mr. Prince, with a
reflector, has seen the satellite dark first and
ds bright. It need hardly be said, that if the
turned always the same face towards its pri-
such varieties of appearance would be pre-
during transit. The following passage from
'Celestial Objects' points strongly also to the
on that the rotation of the Jovian satellites
independent of their revolution. After men-
that the variable light of the satellites may be
by the existence of spots upon their surface, he
: 'A stranger source of anomaly has been
d—the discs themselves do not always appear
ame size or form. Maraldi noticed the former
1707, Herschel ninety years afterwards infer-
the latter, and both have since been con-
Beer and Mädler, Lassell and Secchi, have
es seen the disc of the second satellite larger
t of the first; and Lassell, and Secchi and his
have distinctly seen that of the third satellite
r and elliptical; while, according to the Roman
s, the ellipse does not always lie the same way.'
ill easily be seen that these peculiarities in-
ne existence of dark markings on these bodies,

ange in figure since the brighter part of the satellite uld be that which would determine its apparent ure. And further, since the change of figure shows correspondence with the position of the satellites in ir revolution, we infer that their revolution is in- pendent of their rotation.

It is worthy of notice, however, that even if the ier satellites turned always the same face towards ir primary, the peculiarity would not (as in the case our moon) result in an inordinate lengthening of ir diurnal period, since Jupiter's two inner satellites nplete a revolution in 1 day 18½ hours, and 3 ys 13 hours respectively; while the revolutions of turn's five inner satellites are severally accomplished 22½ hours, 1 day 9 hours, 1 day 21 hours, 2 days hours, and 4 days 12½ hours.

So far as we can judge from Laplace's estimates, specific gravity of Jupiter's moons must be very all, ranging from one-third to two-thirds of the oon's specific gravity. But very little reliance n be placed on these results, because the only dence we have respecting the mass of the satellites that founded on the perturbations to which their tions are subjected, and it is very difficult indeed estimate these perturbations. When to this we add circumstance that little reliance can be placed on asurements of the minute disc presented by the ellites, it will be seen that our estimate of the ecific gravities of these bodies cannot by any means

As seen from his satellites, Jupiter must present a magnificent scene. To the inhabitants, if such there are, of the innermost satellite, he exhibits a disc nearly twenty degrees in diameter. Thus, whereas there might be about 700 moons such as ours placed all round our horizon, the disc of Jupiter, as seen from the inner satellite, would occupy a full eighteenth part of the horizon's circumference. The disc of Jupiter, as so seen, would cover a space on the heavens exceeding more than 1,400 times that which our moon covers. To the second satellite, Jupiter presents a disc about 12½ degrees in diameter, or about 600 times as large as our moon's. To the third satellite he shows a disc about 7¾ degrees in diameter, or more than 200 times the size of the moon's. And lastly, the inhabitants even of the furthermost satellite see him with a diameter of about 4½ degrees—that is, with a disc more than 65 times as large as that of our moon. So that, if the views I have put forward respecting Jupiter be correct, the enormous space he covers on the skies of his respective satellites must suffice to compensate in part for the relatively small amount of heat which he can be supposed capable of emitting.

If the satellites rotate with a motion independent of their revolution, Jupiter passes across their skies like a vast moon, exhibiting phases such as those presented by ours, but on a far vaster scale. But besides his phases, he must exhibit to the inhabitants of his satellites the most marvellous picture that can be conceived. His belts' changes of figure and colour, only rendered sible to our astronomers by powerful telescopic aid, ust be distinctly visible to creatures on his satellites, id cannot but afford reasoning beings on those orbs most astounding theme for study and admiration.

To the inhabitants of the satellites which circle und Saturn, the ringed planet must present an even ore interesting spectacle. His disc as seen from the earest of his satellites has a diameter of 17 degrees id an apparent surface exceeding more than 900 mes that of the moon. From the farthest satellite s disc is less than a degree in diameter, and therefore ot quite four times as large as our moon's. Between ese limits the apparent size of Saturn varies as we ss from satellite to satellite; but from the sixth tellite his apparent surface is twenty-five times, while om the seventh it is sixteen times as large as the oon's; so that the outer satellite is quite excep- onally circumstanced in this respect.

It is not so much from the apparent size of his disc, wever (though in the case of all the inner satellites at must be a most remarkable relation), as from the culiar character of his ring-system, that Saturn would rive his chief interest. It is true that the inner ellites travel nearly in the plane of the rings, so that ese are always presented nearly edgewise. But even viewed, the rings would present a most striking ap- arance. From the inner satellite, indeed, the extreme an of the ring-system is more than 90 degrees;[1] so

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[1] About 93° according to the best estimates of the dimensions

en one extremity is seen on the horizon the
would appear as an arch thickest in the middle,
ng over an arc of about 93 degrees, and having
of Saturn at its centre. When the whole of
n is illuminated, Saturn is 'full'; at other times
ents all the phases shown by our moon, and
n of light is correspondingly shortened. Saturn
nd in the zenith, with the ring-system de-
, on either side of his disc, must be a glorious
e as seen from certain regions of his innermost
. The display would diminish in grandeur,
not perhaps in interest, as seen from satellites
and farther away. But the inhabitants of the
ost satellite of all have the privilege of seeing
urnian ring-system opened out much more fully
seen from the other satellites, since the path of
on is inclined some 15 degrees to the plane of
g.

he satellites of Uranus and Neptune little can
, because so little is known either respecting
rbs themselves or their primaries. It seems
at Sir William Herschel was mistaken as re-
our of the satellites of Uranus he supposed he
tected. Uranus has but four known satellites
ptune only one. Possibly other Uranian satel-
ay one day be discovered, and Neptune also
ssibly have several satellites circling around

CHAPTER IX.

METEORS AND COMETS: THEIR OFFICE IN THE SOLAR SYSTEM.

THERE are few more interesting chapters in the history f astronomy than that which deals with the gradual ntroduction of meteors into an important position in he economy of the solar system. Regarded for a long ime as simply atmospheric phenomena (though many ncient philosophers held another opinion), it has only een after a long and persistent series of researches hat they have come at length to be regarded in their rue light. But though the history of those researches s not only full of interest, but highly instructive nd encouraging, this is not the place for entering at ength into its details. I must present facts and conlusions, rather than the narrative of observations or alculations by which those facts and conclusions have een established. Nay, it would seem at first sight as hough even the nature of meteors could have very ittle to do with the subject of this treatise, since we annot suppose these small bodies to be inhabited vorlds. It will be found, however, that, though this s are associated in a very intimate manner with eral relations of the family of worlds forming r system.

der the head 'Meteors' I include all those objects reach the earth's atmosphere from without, r they actually make their way to her surface en, like the aërolites; or explode into small frag- as bolides and fireballs have been observed to are apparently consumed in traversing the upper of the air, as happens with shooting or falling All these objects, we now know, represent in bodies of greater or less size, which, before ncounter with the earth, were travelling around in orbits of greater or less eccentricity. The masses, though they must be very numerous earth would not once in many ages encounter them), are yet relatively few in number as com- with fireballs, and still more so in comparison ooting stars. It has been calculated, indeed, ese last are so numerous that the earth, in passing a region of space equal to her own dimensions, ncounter no less than 13,000 of them; while of aller bodies, whose passage through our air would recognisable by telescopic aid, she is supposed unter as many as 40,000 within a similar space. t laying great stress on these calculations, we t feel quite sure that the earth must encounter us numbers of these bodies, from the mere fact

ven but a portion only of that slice visible to a single
bserver, six or seven falling stars on the average may
e seen during each hour of the night.

It will be seen, then, that a problem of the utmost
nportance was involved in the question whether these
odies came from the interplanetary spaces, or from
e region of space over which the earth's own attrac-
ve energies prevail. Now that we know the former
ew to be the true one, we recognise the fact that,
ough each meteor may be individually insignificant,
e meteors of the solar system, looked on as a single
mily, form a highly interesting and important portion
the sun's domain.

But now a yet more significant relation has to be
nsidered. Regarding meteors as planetary bodies,
ey might yet be relatively unimportant, if we had
y reason to believe that they form a sort of zone or
lt near the earth's orbit, resembling in a sense the
teroidal zone, only composed of far smaller consti-
ent bodies. We could not *then* infer from the number
meteors encountered in a given time by the earth,
e largeness of the total number of these bodies; for
might well be that this zone had no counterpart,
ther in the outer part of the planetary system or
ithin the orbit of the earth. What has actually been
scovered, however, respecting the paths along which
e meteoric bodies have reached the earth, immensely
hances the importance of these objects.

It has been proved, on evidence perfectly incontests of enormous eccentricity. The August meteors el on a path so eccentric that in the neighbourhood ne earth's orbit it may be regarded as almost para- in figure. That it is not absolutely parabolic is vn, of course, by the fact that a period has been ned to the revolution of the members of the zone. bservations have indeed been made by which as- omers could determine the orbit of these meteors, e for this purpose an exact determination of the ity with which they enter the earth's atmosphere d be requisite, while the observations actually e to determine their velocity are confessedly in- t. But an association, altogether too close to be rded as accidental, has been discovered between orbit and that of a bright comet which appeared 862, and this, combined with what has since been blished respecting the relations between comets and ors, enables astronomers to adopt quite confidently rbit of the comet as that of the meteoric system: a period of 145 years implies, according to Kepler's an orbit having a mean distance nearly equal to of Neptune. And since the orbit is so eccentric bring these bodies close to the earth when they near perihelion, it follows that their aphelion nce must exceed their mean distance in the same ee. Hence the aphelion point of the August eors must lie nearly twice as far away from us as rbit of Neptune.

n, the aphelion of their orbit lying far beyond the
th of Uranus.

So far, then, as we can judge from the only two
eteoric systems whose orbits can be said to have
een satisfactorily determined (though there are many
her systems which have been associated with known
mets), we are led to the conclusion that the meteoric
bits are for the most part eccentric. We know,
rther, that they are inclined in all directions to the
ane in which the earth travels, because we see that
eir constituent bodies fall upon the earth in direc-
ons which shows no tendency to near coincidence with
e ecliptic.

These two circumstances are full of meaning. If
e meteors travelled in nearly circular orbits at a
ean distance nearly equal to the earth's mean dis-
nce from the sun, then the earth would be certain to
counter meteors in the course of her orbital motion
und the sun. Again, if the meteors travelled in
centric orbits, whose perihelia lay within the earth's
bit, and if these orbits all lay in or near the plane of
e earth's path, the earth could not fail to encounter
eteors as she travelled round the sun. But under the
tual circumstances—the mean distances of the me-
oric orbits being in no way associated with the earth's
ean distance, and the inclination of these orbits to the
liptic not being in any way limited—the two questions
e at once suggested, (1) What is the *à priori* chance
at the earth would encounter the members of any

all, what is the conclusion to be drawn from the
hat the earth encounters meteors belonging to
systems?—the number already recognised being
sixty. Assigning elements at random to a
r system, we see that, unless the resulting orbit
ly coincides with the plane of the ecliptic (a
on which would not happen in a million trials), the
will intersect that plane in two points, lying on
ight line through the sun. And for the earth to
nter members of the meteoric system, it is requi-
at one or other of these two points shall lie close
earth's orbit. But these points may have any
on whatever in the plane of the ecliptic, and the
e that one of them has the requisite position may
garded as indefinitely small. It follows, then,
he *à priori* chance of the earth's encountering the
ers of a meteoric system is indefinitely small;
ence we conclude that the number of meteoric
ns of which she passes wholly clear is indefinitely
in comparison with the number whose members
ncounters. But she actually encounters meteors
ging to more than four hundred systems. Hence
tal number of meteoric systems belonging to the
ary scheme must be an indefinitely large number
ndreds—or in other words, it must be enormously
d our powers of conception.

is being so, it behoves us to inquire, first of
hat extent we must assign to individual meteoric

vhat may be the nature, quality, and substance of hese meteoric masses. For we begin to see that we re in the presence of relations which may—or I hould rather say which must—affect most importantly he economy of the solar system.

Now we have seen something already of the longiudinal extent of meteoric systems, since that extent corresponds to the circumference of meteoric orbits, nd we have seen that these orbits have enormous limensions. We may indeed suppose that in some ases the whole extent of an orbit is not occupied by neteoric masses at any one instant: but even when, s in the case of the November meteors, the annual lisplays wax and wane in splendour, there is no absolute essation in the occurrence of star-falls on the date coresponding to such a system. And taking full account ven of the marked diminution which actually occurs ve are yet compelled to assign an enormous longiudinal extent to that portion of the system which has peen poetically termed 'the gem of the meteor-ring.' 'or example, in the November meteor system, this portion of the ring cannot be less than 1,000,000,000 niles in length. As to the width of a meteor system—hat is, its extent in a direction measured in the plane of its orbit—we have no satisfactory information, because a meteor system may extend enormously on either side of the point through which the earth's orbit intersects t, and yet no trace of that extension be recognised by observers on the earth. Still we may conclude

ngitudinal extension of the system and the depth
e meteor zone—that is, the length of a line taken
gh it, square to the plane in which it lies. Now
s last dimension we can form a tolerably accurate
ate in many instances. We know that so long as
ors belonging to any system are flashing into view,
arth is still plunging through the system; and if
now the position of the system, we can determine
pth in this way, just as we could determine the
th of a range of hills if we noticed the time oc-
d by a train, travelling with known velocity, in
g through a tunnel which traversed the range of
in a known direction. Judged in this way, the
of the November meteor zone would seem to be
00 miles in the part traversed by the earth in
about 60,000 miles in the part traversed in
and considerably greater (though the zone was
sparsely strewn with meteors) where the earth
d the system in 1868, 1869, and 1870.

ow as regards the density with which meteors are
n in any known system, I must remark on a
ke which has been sometimes made. It has not
thought necessary to consider the velocity with
the meteors themselves travel, as well as the
s velocity, in order to determine from the average
al of time separating the appearance of successive
rs the average distance separating neighbouring
rs from each other. This, however, is an erro-

otions manifestly tend to affect the total number of
ncounters.[1] Let us apply this consideration to en-
le us to form a rough estimate of the number of
dies in the richer part of the November meteor
stem. We may fairly assume that, taking the
erage of the four displays of the years 1866–69,
e earth encountered more than one meteor per
inute as she swept onwards through the system;
, conveniently for our purpose, that an average
stance of 1,000 miles separates meteor from meteor
roughout the 'gem of the ring.' Now the length of
e great cluster is at least 1,000,000,000 miles, its
ickness may be fairly assumed as averaging 100,000
iles, and its width can hardly be less than ten times
s thickness, since the forces acting on the system
nd much more largely to affect its width than its
ickness. Thus, with the assumed average of dis-
nce (1,000 miles), we find that the cluster cannot
ntain less than (1,000,000 × 100 × 1,000) or one
ndred thousand million meteors!

Prof. Alexander Herschel, from observations of
e amount of light given out by these bodies, and a
lculation founded on the velocity with which they
netrate our atmosphere, has come to the conclusion

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[1] Obviously the total number of meteors encountered during
e earth's passage through a meteor stream will be the number
ntained in a cylindrical space having a cross-section equal to the
rth's, and traversing the meteor stream from side to side. The
otion of the meteors will affect the particular set of meteors
tually found within this space as the earth traverses it, and will

that they must, for the most part, be very small, rarely, perhaps, exceeding a few ounces in weight. We shall certainly not exaggerate their weight if we assign one-hundredth part of an ounce to each. We thus obtain for the weight of the whole cluster one thousand millions of ounces, or about 28,000 tons. The actual weight of the November meteor system cannot however but enormously exceed this amount; and therefore we recognise how erroneous that opinion is which an eminent astronomer has expressed, who asserted that the united weight of all the bodies other than planets in the solar system must be estimated rather by pounds than by tons. We have certainly no reason for thinking that the November system, though one of the most important encountered by the earth, is exceptionally important in the solar system. On the contrary, we have every reason which the laws of probability can afford us for believing that there must be millions of systems equally or more extensive. And further, the fall of enormous masses, many tons sometimes in weight, upon the earth, would point to the conclusion that the members of the November system are exceptionally insignificant as regards their individual dimensions. So that we seem forced to the conclusion that the aggregate weight of the various meteoric systems circulating around the sun must be estimated by billions of tons rather than by any of our ordinary units.

I have already referred to the relation which has been detected between comets and meteor systems.

erplexing as the relation appears, it has been esta- ished on evidence which cannot reasonably be dis- ted. It carries with it results of extreme interest d importance.

I do not propose here to enter into any considera- on of those enormously difficult questions which are ggested by the study of cometic phenomena. That ey will before very long receive their solution I nfidently believe; but in the present state of our owledge it would indeed be hazardous to speculate to what that solution may be. I may remark, in ssing, that while I recognise in recently promul- ted theories on the subject the indication of a ghly suggestive and promising line of research, I nnot but feel that cometic phenomena are far too mplicated to be directly accounted for in any of the ys pointed out of late by physicists. Some of the ore obvious, and, I may add, the more generally own phenomena, do indeed appear to receive a ution when examined under the light of recent searches, but numbers of others not only remain accounted for, but stand apparently altogether posed to suggested theories.

For my present purpose, however, the facts to be ncipally noticed are in a sense independent of any ews which may be formed respecting the nature of mets. We know that the dimensions of these objects e in many cases enormous. We know, further, that ere must be many thousands of comets remaining

d. And, lastly, we are led to recognise the ed association between certain meteor systems rtain comets as indicative of a general law by in some way as yet unexplained, comets and s are associated together. Thus, independently considerations already adduced, we are led to nclusion that meteor systems must be very nu- ; while from the fact that a meteor system so ant as the November stream is associated with a so insignificant as Tempel's, we conclude that magnificent comets which have blazed in our -a source at once of wonder and perplexity to tronomer—must be associated with systems of incalculably more important than the meteor which has so often filled the heavens with stars.

nbining all these results, we seem fairly led to nclusion that purposes of importance in the ny of the solar system are probably subserved se uncounted thousands of meteoric streams. eed, we could suppose that the planets steered f them, and that the bodies composing them circulated unceasingly in their orbits, we form another opinion. But we know that s are continually falling upon the atmosphere of n earth, either there to be dissipated into finest r to pass onwards, with or without explosion, to ual surface of the earth ; and we cannot doubt

e solar system, but upon asteroids and satellites—
y, are even streaming in among the minute bodies
mposing the rings of Saturn. These encounters
nnot be wholly without result, and it is quite con-
ivable that most injurious consequences might ensue
the inhabitants of all the worlds in the solar system
the continual supply of meteoric matter were im-
rtantly diminished.

Now, if meteoric masses fall continually upon the
anets, such masses must fall in numbers inconceiv-
ly greater upon the sun; and it is here, unless I
istake, that the great purpose of the meteoric systems
comes apparent.

Let us clearly recognise, however, why and how
e sun must be assaulted by a continual inrush of
eteoric bodies. We have seen how enormous must
the number of these bodies; we know how swiftly
ey travel, and on what eccentric orbits; but we
ust go farther before we can prove that they fall
on the sun. For example, the November meteors
e enormous in number, and travel with enormous
locity in a very eccentric orbit, but they do not ap-
oach the sun within a distance of nearly 90,000,000
iles. Nor, indeed, can any known meteoric system
ur a steady hail of meteors, so to speak, upon the
n; for he is the ruling centre of every meteoric sys-
m, and therefore under ordinary circumstances the
eteoric orbits must pass around him, and not in such
rections as to intersect his substance.

ely more crowded in the neighbourhood of the ıan at a distance from him. An indefinitely number of meteoric orbits must absolutely in- , in the immediate neighbourhood of the sun; ollisions must be continually taking place as ess thousands of meteoric flights rush towards st and then away from their perihelia. Where perihelia lie close to the sun the velocity with the meteors travel must exceed 200 miles per , and therefore the collision even of two minute 's must result in the generation of an enormous t of light and heat. But that is not all. gst the collisions thus continually taking place sun's neighbourhood there must be a consider- roportion in which the two bodies are brought ntarily almost to rest by the shock. In such he combined mass of the two meteors would fall y upon the sun, a fresh supply of light and heat generated as they were brought again to rest is surface.

ıether in the continual collisions of meteors st themselves, and in their precipitation upon n's surface, we have a sufficient explanation of emingly exhaustless emission of light and heat he sun, I should not care positively to assert. . Thomson, who was one of the first to adopt ew, has now abandoned it; though it is worthy eteors on the sun's surface is not *alone* sufficient to count for the solar light and heat. But so far as I n judge, there is no flaw in the evidence I have duced from the laws of probability applied to re- nt discoveries; and that we are bound to accept a legitimate conclusion from that evidence the eory that at least a proportion of the sun's heat supplied from the meteoric streams which circu- te in countless millions around him. It can no nger be believed, however, without adopting un- asonable assumptions, that the whole of that enor- ous supply of light and heat which the sun nits on every side is derived from the meteoric reams belonging to the solar system or drawn in om surrounding space, as the sun, attended by his mily of planets, sweeps onwards amid the stellar oups.

If this view were correct, then the meteor systems ould constitute indeed a most important part of the n's domain. They might be said almost to share th the sun a title to be regarded as the source of all e forms of force which exist throughout the solar stem. If in the energies of living creatures on rth, in the forces derived from the fuel that propels r engines, or in the power of winds and storms, we ace the action of the ruling centre of the solar stem, we might trace back the chain of causation yet e link farther, and see in the sun's emission of light d heat the result of forces inherent in the meteoric ystems which circle around him.

t we must not forget one most important con-
ion, which would make the sun (as might be
ated) again the chief source of all the forms of
xisting within his system. The motions of the
ic masses are almost wholly due to the sun's
ion; and therefore, in so far as those motions
oe regarded as a means of renewing the solar
ve must regard the sun's attractive energy as
ırce whence his heat and all the other forms of
hich he exerts are in reality derived.

; one step farther. The sun's attractive energies
be increased a thousand-fold, and yet not avail
ly the various forms of force which are required
dependent worlds, were there no external mate-
which those energies could act in such sort as
l to the continual inrush of matter upon the
ırface. Nor would it suffice if such materials,
ı enormous quantities, existed *close* to the sun.
ıe distance from which that material is dragged
s the sun which gives that orb the power of
ing those tremendous velocities to which the
ns of the meteoric bodies owe their real effect-
. We thus find in *distance*, in the simple
t of *scale*, the true source of the various forms
e which are continually exerted throughout the
ystem. The sun surrounded by millions on
s of meteoric masses close at hand would be
; but placed as ruler over a space far wider

stributed, he becomes forthwith the centre of a
ousand forms of energy, gathered by him continually
om the systems of meteors circling around him, and
stributed by him abundantly and without ceasing to
s dependent worlds.[1]

It will not fail to be noticed by the thoughtful
ader that, adopting this view of the relation in which
eteoric and cometic systems stand with respect to
e sun, it seems necessary that we should regard
ose planets which I have endeavoured to raise to
e dignity of secondary suns, as subordinate centres
attraction, around which countless thousands of
eteoric systems may be supposed to circle. Have
any evidence pointing to such a conclusion?

Now there can be no doubt that if Jupiter, the
arest of these secondary suns, did so act upon a
ssing comet as to compel that body to circle in
ture around *him*, instead of pursuing its course
ound the sun, we could not in any way become
gnisant of the event unless the comet were an exceptionally
large one. I conceive, however, that such

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[1] Just as this work (the first edition) was about to be placed
the printer's hands I received from Professor Kirkwood, of
nerica, one of his valuable contributions to the history of the
ar system. In it he points to the evidence we have that the sun,
he speeds onwards through space, passes through regions in
ich cometic and meteoric materials are now richly, now sparsely
ewn, and gathers in accordingly new stores of force of greater or
s amount. The bearing of the views of this acute and soundly
soning astronomer (the Kepler of our day), not only on the

nt, though undoubtedly possible,[1] must be so
mon that the number of cometic systems thus
to own Jupiter as their centre of attraction
be relatively few. But in another way the
does exhibit his power as a comet-ruler, making
recognise him as a sort of subordinate master,
n being their primary ruler. When comets
from outer space pass near enough to Jupiter,
ys them so markedly from the orbit they are
ıg that the scene of encounter becomes the
n of their orbit, or nearly so. Thence they
their new orbit to their perihelion, returning
presently to the scene of their encounter with
, and so revolving in an orbit having its
n close by the orbit of Jupiter, until haply the
is again near the scene of encounter at the

ıs necessarily possible in the case of any planet, but must
cases be highly improbable. For example, astronomers
es assert that meteoric masses passing near the earth
ecome satellites of hers; but in reality this is a very un-
ent, because the maximum velocity which a body travelling
e earth's influence can have (that is, the velocity acquired
y travelling from infinity to a perigee close to the earth)
han the velocity with which a body circling on any orbit
e sun would move when at the earth's distance from him,
s orbit were very eccentric and the aphelion close by the
rbit. Bodies travelling from outer space towards the sun
y any possibility become satellites of the earth, because
uld always have a velocity greater than that which her
n can master. Even in the rare event of their grazing
osphere, and so losing a large share of their velocity, they
t become permanent satellites of hers, because, returning

moment when the comet comes back to it. In this ase a fresh struggle takes place, the overmastering ttraction of the planet necessarily prevailing, and the omet being often dismissed on a new orbit, whose erihelion, instead of its aphelion, lies close by the rbit of Jupiter.

Now we know that such events as these must be f frequent occurrence as Jupiter sweeps swiftly round n his orbit. For we recognise several comets which ave evidently been compelled by Jupiter to take up uch orbits as I have spoken of—a family of comets, n fact, including Encke's, Faye's, and Brorsen's, Winnecke's short-period comet, and several others. We judge further, from the laws of probability, that or each discovered comet of this family there must e thousands which have escaped detection. So that round the orbit of Jupiter (if not around Jupiter imself) there cling the aphelia of myriads of ometic orbits whose perihelia lie at all conceivable istances from the sun less than the distance of upiter.

Saturn also has his family of comets; so also have Uranus and Neptune. The comet associated with the November meteors belongs indeed to the Uranian omet-family, and the epoch (126 A.D.) has even been pointed out when this comet may have fallen under the dominion (subject always to the sun's superior control) of that distant planet.

And here I may refer to a view which I have long ntertained respecting the purposes which meteoric and cometic systems have fulfilled in the past history of the solar system.[1] We know that the materials composing meteors, and we conclude, therefore, that those composing comets, do not differ from those which constitute the earth and sun, and presumably the planets also. Therefore under the continual rain of meteoric matter it may be said that the earth, sun, and planets are *growing*. Now the idea obviously suggests itself that the whole growth of the solar system from its primal condition to its present state may have been due to processes resembling those which we now see taking place within its bounds. It is of course obvious that if this be the case, the number of meteoric and cometic systems must have been enormously greater originally than it is at present. Countless millions of meteoric systems,. travelling in orbits of every degree of eccentricity and inclination, travelling also in all conceivable directions around the centre of gravity of the whole, would go to the making up of each individual planet. A marked tendency to aggregate around one definite plane, and to move in directions which, referred to that plane, corresponded to the present direction of planetary motion, would iffice to account for the present state of things. The fect of multiplied collisions would necessarily be to iminate orbits of exaggerated eccentricity, and to rm systems travelling nearly in the mean plane of ie aggregate motions, and with a direct motion. urther, where collisions were most numerous, there ould be found not only the most circular resulting bits, not only the greatest approach to exact coin-dence of such orbits with the mean plane of the whole ystem, but the bodies formed out of the resulting ystems would there exhibit rotations coinciding most early with the mean plane of the entire system.[1]

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[1] Since the present chapter was written, I find that the hypothesis here put forward has in a general way been touched on by more than one astronomer and physicist. I believe, however, that here, for the first time, it has been associated with the chief features of the solar system. It was suggested in note B (Appendix) to my treatise on Saturn. But as a matter of fact, when that note was written, as also when those passages were published in which the same hypothesis is dealt with by other authors, decisive evidence in favour of the theory was wanting.

It seems to me that not only has this general view the mode in which our system has reached its pre-nt state a greater support from what is now actually oing on than the nebular hypothesis of Laplace, but at it serves to account in a far more satisfactory anner for the principal peculiarities of the solar stem. I might indeed go further and say that here these peculiarities seem to oppose themselves to aplace's theory, they give support to that which I ive put forward.[2]

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[1] This conclusion depends on a well-known law of probability. may be thus illustrated :—If we have in a bag a million white d a million black balls, and take out at random a number of balls, en the larger that number, the more nearly (in all probability) ll the number of black and white balls included in it approach to atio of equality.

[2] It is scarcely necessary to remark that as regards at least the ger members of the solar system—including the four primary ucts within the zone of asteroids—the nebulous condition in-

example, what is there in the nebular hypothesis
ffords even a general explanation of the strange
s of size observed in the planetary system?
n that hypothesis be reconciled with the re-
le variations of inclination observed among the
, or with the retrograde and almost perpendicular
of the satellites of Uranus? Nor, again, is the
esis consistent with the observed peculiarities of
of those meteoric systems which we must now
as regular members of the solar system.

v, according to the hypothesis I have put forward
a general explanation of all these matters is as
ggested. Let us consider:—

the neighbourhood of the great central aggre-
which would undoubtedly result from the mo-
f such meteoric systems as I have considered,
motions would be very rapid. They would, in
esemble the motions now actually observed in
's neighbourhood. Here, therefore, subordinate
ations would form with difficulty, since they
have small power of overruling meteoric systems
with so great a velocity past them. In the
nmediate neighbourhood, then, we should expect
relatively small planets; and we do accordingly
t Mercury, nearest to him, is the smallest of the
, Venus larger, and the earth (yet further away)
y larger than Venus, but adorned with an attend-
llite.

Now, at a much greater distance from the sun the ıeteoric motions would be so much less that here, upposing only a suitable mean density of aggregaıon, it would be possible for much larger suborinate centres of aggregation to form. These centres ould increase in importance as they swept round ıe central aggregation, continually gathering fresh ·ecruits. Indeed, though, *as now*, they would not e able to prevent the major part of the materials ıshing from outer space towards the sun from aggreating round *him*, they would still gather in no inonsiderable portion of those materials. Where the ırgest portion would be gathered would depend on ıe way in which (taking a general view of the ystem) the quantity of material increased towards the eighbourhood of the centre. For clearly, while disınce from the sun would increase the facility with which ıaterials would be gathered in—since the sun's influence ould diminish with distance it would also affect the uantity of material available—since, from a very early eriod, the system must have begun to show an appearınce resembling that now presented by the zodiacal ght—that is, a general increase of density towards the entre.

Assuming that the region of maximum aggregation as that where the influence of the ruling centre first ecame so far diminished with distance as to render the ormation of a great subordinate aggregation possible, e should have the innermost of the outer series of

t giant planet we should find a relatively barren
cleared of material not only by the sun's still
ful influence, but also by the influence of this first
tant subordinate aggregation. The initial assump-
s, in itself, at least not improbable, and having
dmitted it, we find an explanation of the giant
of Jupiter, of the comparative poverty of material
ithin the orbit of Jupiter, and hence of the
ion of the asteroidal zone, and of the smallness
planet Mars next within that zone—though this
far outweighs (according to Leverrier's estimate)
nited mass of all the asteroids. Beyond the
of Jupiter, we should expect (after passing an
ously wide space, bare of worlds) to find still a
abundance of material, and an even greater
y in the aggregation of that material. Thus the
nce of the planet Saturn, next in importance to
r, and surpassing him in the complexity of his
ant system, is accounted for; yet farther away, we
r and find still an abundance of material, and
aterial somewhat more uniformly strewn, while
n's small influence is indicated by the existence
llites, of which doubtless many more will one
discovered by astronomers.

to the rotations of the various members of
ar system we find some account, necessarily not
given by this theory. I have mentioned above
ults to be looked for: those observed are closely

thin its inner division, has its equator inclined but
out seven degrees to the mean plane of the system.
ars, the least member of this system, has an inclina-
on of no less than twenty-eight degrees; the larger
rth an inclination of but twenty-three degrees. The
clinations of Venus and Mercury are undetermined;
ey may be expected to be large, not merely on ac-
unt of the smallness of these bodies, but on account
their proximity to the sun. Of the outer division of
e system, Jupiter, the largest, has an inclination of
tle more than three degrees; Saturn has a very con-
lerable inclination (more than twenty-six degrees);
ranus has an inclination which may be described as
tually greater than ninety degrees, since he rotates
ckwards with his equator inclined seventy-six de-
ees to the ecliptic. And lastly, if the observations
therto made on Neptune's satellites are to be trusted,
is planet probably rotates in a retrograde manner,
s equator being inclined some twenty-six degrees to
e horizon; so that, to render the comparison between
s rotation and that of the other members of the solar
stem complete, he may be said to rotate in a direct
anner with his equator inclined some 154 degrees to
e ecliptic.

The great inclination and eccentricity of many of the
teroidal orbits is also accounted for more satisfactorily
this theory than by the nebular hypothesis. There
perhaps no absolute incorrectness in the assertion
at the smallness of the asteroids explains (on the

of their motions. Their minuteness doubtless them (when long intervals of time are con-) more under the disturbing influence of Jupiter single massive planet at the same distance from ı would be.[1] But the attraction of Jupiter can y have been sufficient to cause the asteroids rt so widely as they do from the ecliptic, since h lies quite close to the ecliptic, and even nearer mean plane of the solar system. Bodies formed asteroids are supposed to have been, according hypothesis I have suggested, would necessarily a much greater variety of motion than would gnised in the case of the larger planets.

e most eminent astronomer of our day indicated in a communication an objection to this sentence (originally without the parenthetical passage), founded on the fact disturbance by Jupiter of a single planet as large as the r even Neptune) travelling on the orbit of one of the aste- ould be precisely the same as the disturbance of the or even of a much minuter body—as a meteor or a pepper- his is just; but the contrary was not meant to be implied oove sentence as it originally stood. It was to the influence r in long cyclic periods, during which the reflex actions due hanges in Jupiter's own orbit through the action of the d body came into play, that I referred. In the case of ets of nearly eqnal mass—or of masses comparable in mag- there is an interchange of eccentricities and inclinations, e can never become very large for either planet. It is , however, when one of the bodies is exceedingly minute, the orbit of the larger changes so slowly that perturbing re renewed again and again, during a very long cycle, so ore the reverse processes begin to act a very considerable ity or a very considerable inclination may be given to the body. That this is so is shown by the much wider

Another point in which, as I conceive, my hypothesis
more satisfactory than the nebular one consists in
e fact that it suggests an explanation of the pecu-
rities observed in the planetary periods. Professor
rkwood's researches into the various relations of
nmensurability presented among the periods of
ncts and satellites, and the known effects of com-
ensurability in encouraging the accumulation of
netary perturbations, will at once suggest to the
thematical reader the way in which a system form-
g in such a manner as I have imagined might be
pected to exhibit the presence of law as regards
stances and periods. There is nothing in the nebular
pothesis which encourages the belief that a system
med as Laplace conceived the solar system to be,
uld exhibit any such laws as are found within the
netary scheme.

The hypothesis I have put forward also gets rid
what has always seemed to me the great diffi-
lty of the nebular hypothesis. According to the
ews of Laplace, Neptune must have been formed
llions of ages before Uranus, Uranus as long before
turn, Saturn as long before Jupiter, and so on.
ow we know that the appearance of those primary
embers of the solar system which we are best able to
ndy does not indicate any such enormous dispropor-
n in the ages of the planets, even if it does not
dicate that the planets were formed nearly at the
me era. According to my hypothesis, the various

ıs the influences which Jupiter *now* exerts on s act simultaneously with the more power- fluences exerted by the sun); and though the s orbs formed by those processes would not arily be completed simultaneously, there would such enormous disproportion in their age as is ary according to the theory of Laplace.

t another strong point in favour of this hypothesis s in the circumstance that we now have every to believe that all the planets are constituted of me elements. When it was thought that Jupiter be a watery globe, for instance, there was some ce in favour of Laplace's theory. But we now that Jupiter is not constituted differently, in all bility, from the earth and sun, as according to e's theory he must have been. Since, then, we that meteors contain the same elements which n the constitution of sun and planets, we have very strong argument in favour of the view that ave played the important part I have assigned to n the formation of the solar system.

t after all, the strongest evidence in favour of the esis I have suggested consists in the fact that ocesses by means of which I conceive the solar to have been formed are undoubtedly going on our eyes. There may be little, indeed, in the ll of meteoric showers to suggest the idea of formation or sun-formation; little in the present

lomeration of meteoric and cometic systems, all
eding with inconceivable velocities on their inter-
ng orbits, which I imagine to have been the em-
on of the solar scheme. But sun and planets *are*
wing, however slowly, as the meteoric hail falls
tinuously upon them; the zodiacal light and the
r corona *are* doubtless due to the existence of
teoric systems, resembling (however relatively insig-
cant) those which I have pictured as the materials
he planetary scheme. In the Saturnian rings, also,
ich have been proved by the researches of Maxwell
l others to consist of multitudes of discrete bodies,
have evidence of the same sort in the case of a
ordinate centre of aggregation. So that we have
rm of evidence, which was wanting in the case of
nebular hypothesis, in favour of this other hypo-
sis, by which, as in Laplace's, the present state of
solar system is regarded as the result of a process
levelopment, and not of special creative fiats.

CHAPTER X.

OTHER SUNS THAN OURS.

We are now to venture into regions where we shall no longer have clear lights to guide us. Tremendous as are the dimensions of the solar system, the widest sweep of the planetary orbits sinks into insignificance compared with the distances which separate from us even the nearest of the fixed stars. From beyond depths which the human mind is utterly unable to conceive there come to us the rays of light which myriads of those orbs are pouring forth, and it is from the lessons taught us by these light-rays that we are to form our ideas concerning the nature of the orbs which emit them. Very carefully and cautiously must we proceed, if we would avoid being led into vain imaginings. It will but mislead us to pass a single step beyond the path which is dimly lighted for us, and yet that path is so narrow and so obstructed with difficulties that we find ourselves continually tempted to leave it, and to venture forward on the alluring and easy paths which speculation opens out on every hand around us.

And yet we may well remain content to listen only the teachings of known facts. Even so restraining rselves, we have in reality a wide and noble domain explore. Facts which seem severally unimportant, found, when considered as parts of a grand whole, indicate relations so impressive and so interesting at the revelations of the telescope within the solar stem are apt to seem commonplace beside them. e have, in fact, no longer to consider the structure a system—the architecture of the universe is our eme.

Let us examine carefully the evidence which science s gathered together for us, endeavouring at each p to gain the full amount of knowledge the several ts involve, while at the same time cautiously refraing from any attempt to overstep the bounds indicated our evidence.

In the first place let us consider what may be rned from the analogy of the solar system. The dy is an inviting one, since the discoveries on which are to found our views have been made so recently it the subject has all the charm of novelty and freshss, while it involves the consideration of the soundest d most instructive mode of pursuing our researches.

We have seen in the solar system a variety and mplexity of structure, such as, half a century ago, v astronomers would have thought of ascribing to When Sir William Herschel began that noble ies of researches amid the sidereal depths by which name has been rendered illustrious, he saw in the is presented to our contemplation. He beheld central body, surrounded by a limited number , some of which are the centres of subordinate s of greater or less extent. When we have the ring of Saturn as the only formation differ from planets and satellites in character, and the , few and far between, which seemed rather acci- tributaries of the sun than regular members family, we have considered all the features which ar system, as known in Sir William Herschel's esented to the contemplation of astronomers.

th us it is very different. We see that there within the solar system a variety of size and re, of motion, arrangement, and aggregation, is already inconceivable, and yet doubtless but shadows forth the real complexity and richness scheme swayed by our sun. Perhaps it is in ering the solar system in the particular light in in this treatise, I have had occasion to present this wonderful variety of conformation is made trikingly apparent. But, apart from all specu- theories, there can be no doubt that the solar presents to us a subject of study amazing in but most amazing when we regard it as sup- the analogies which are to guide us in forming ews respecting the sidereal system. Besides the of planets circling round the sun, besides the of dependent orbs which circle round the

e solar orb; we see the ring of Saturn composed
thousands of tiny bodies; we see the meteoric
stems in countless hosts; we see the comets of our
ieme in millions on millions; and less certainly, but
ll not indistinctly, we recognise the existence of a
iltitude of new and hitherto unsuspected forms of
itter within the circle of our sun's attraction.

What opinion then are we to form—even here, at
e very outset of our inquiry—respecting the sidereal
ieme of which our sun forms but an unit? Surely
would be to lose sight of the significant lesson
ight us by the solar system, it would be to forget
v sure and safe a guide the greatest of modern
ronomers found in the teachings of analogy, to
opt the same view now which that great astronomer
opted a century ago. If, viewing the solar system
consisting of discrete orbs, comparable one with
other in size, and distributed with a certain
formity around their ruling centre, Sir William
rschel held that the sidereal scheme presented
iewhat similar relations, surely *we*, who know cer-
ily that the solar system is constituted so differ-
ly must adopt a far different view of the sidereal
tem also.

Let us remember that there is here—so far as our
pect and admiration for Sir William Herschel are
cerned—a choice between two courses. Assuming,
ndeed is just, that the views of our great men are
rashly to be thrown on one side, we have to choose

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William Herschel formed about *facts*, or the views which he formed about *principles*. If we accept his opinion (or rather, after all, his mere suggestion), that the stars are tolerably uniform in magnitude and distribution, we must abandon the analogy of the solar system. If, on the contrary, we accept Sir William Herschel's often expressed opinion that, in theorising about the unknown, there can be no safer guide than the analogy of known facts, we must abandon the view (which seemed to him but probable) that the stars are distributed with tolerable uniformity throughout our galaxy, and are comparable *inter se* in magnitude and splendour.

There can be no doubt which course is preferable. We know certainly that Sir William Herschel was often mistaken, as all men must be, in matters of fact; while we know with equal certainty that he owed the marvellous success with which he theorised to his adoption of the principle that analogy is the chief and the best guide for the student of astronomy.

We are compelled, then, in our very respect and admiration for the greatest astronomer of modern times, to regard the constitution of the sidereal system as, in all probability, very different from what he imagined. We must be prepared to expect an infinite variety of figure, of structure, of motion, and of aggregation throughout the galactic scheme. If some orbs within that scheme seem probably to be suns like our own, we must not be surprised to find others which are probably far larger or far smaller. We may look for

ects differing as much from the suns of the sidereal
tem as the asteroidal zone differs from Saturn or
m Jupiter. So that, if we should recognise evidence
the existence of clusters of minute stars—a whole
ster, perhaps, not equalling in real importance the
st of the suns of the system—we may accept that
dence without any scruple suggested by the im-
bability of the conclusion to which it points. Again,
may expect to find schemes within the sidereal
tem, differing as much from discrete stars or star-
sters as the rings of Saturn differ from the primary
nets or from the asteroidal zone. So that, if we
uld recognise evidence of the existence of relatively
nute clusters, whose components are either so small
so closely aggregated as not to be separately visible
n in our most powerful telescopes, this evidence
y fairly be accepted as accordant with the only
logy we have for our guidance. Yet once more: we
y look for systems differing as much from all or-
ary star-clusters as the excentric and far-reaching
teor systems differ from the symmetrical rings of
urn. So that, if we should find evidence of strange
emes within the sidereal system, schemes presenting
nge varieties of figure, with strange complexities
spiral whorls or outlying branches, losing them-
ves, as it were, in the depths towards which they
m to extend—this also need not surprise us: we
d not conclude that *here*, at any rate, we are looking
yond the bounds of the sidereal system, and gazing

guidance teaches us that such structures were
xpected within the scheme of which our sun is
onent. And finally, if we should find reason to
ourselves that there are objects in the depths of
vhose very substance and constitution are dif-
rom those of all other objects within the sidereal
we need by no means believe that the objects
ngularly constituted belong to or form external
s. For the millions on millions of comets which
art and parcel of the solar system present a
y analogous difference of structure, as compared
e other members of that system.

ving thus replaced the erroneous analogies to
-through no fault of his own—Sir William
el was led to look for guidance, by the more
rthy analogies which the recent progress of
my has afforded for our instruction, we may
l to consider the direct evidence we have
ing the constitution of our galaxy.

the first place, let us examine the evidence
g to the dimensions of the sidereal system.

t the nearest members of the system lie at enor-
istances from us is proved by the fact that, as
th sweeps on her vast orbit round the sun, no
able change is observed in the configuration of
r-groups. That a circle having a diameter of
han 185,000,000 of miles should be swept out
year as the earth traverses her orbit, and yet

idence we have of the enormous scale on which e sidereal system is constructed. And yet this first vious fact sinks almost into insignificance when we gard thoughtfully the teaching of modern instru- ntal astronomy. There might be a real shifting apparent position which yet the unaided eye would l to detect, and such a change would indicate stances so enormous that the mind fails altogether conceive their real significance. But the exact struments of modern times would exhibit a change place far more minute than any which the un- led eye could recognise. If a star shifted by so ich as the ten-thousandth part of the moon's apparent ameter, modern astronomers could assure themselves the change of place. And when we remember that precisely the same proportion that we increase the actitude of instrumental observation we increase o the significance of the stars' apparent fixity of sition, it will be seen at once how astounding is the sson conveyed by the fact that all but a very few leed of the stars remain absolutely unaffected—even der the most powerful instrumental examination— the enormous range of the earth's orbital motion.

We can roughly estimate the distances of the few rs which are thus affected, and thence—on the pothesis that the intrinsic brilliancy of their light the same as the sun's—we may form some idea of eir dimensions. I shall, however, only apply this ocess, in detail, to a single case, because my present

ich the sidereal system is constructed than to
at length on the more exact details which find
place in ordinary treatises on astronomy.

e star Alpha Centauri is one of the brightest in
eavens, Sirius and Canopus alone surpassing it
endour. But it was not its exceptional brilliancy
which led astronomers to regard it as likely to
evidence of an apparent change of place corre-
ing to the earth's real change of place as she
s round her orbit. Of course, the brightest
are presumably the nearest; but there is another
tion of proximity at least equally important.
o-called fixed stars are in reality slowly moving
ds on definite courses—slowly, that is, in appear-
though in reality their motions are doubtless
eivable rapid. Now these motions, the *proper
ns* of the stars, as they are called, are as yet very
understood. We know only that the whole of
lactic system is astir with life, but whither the
re severally tending we are not yet able to say.
o we know what portion of the stellar motions
e due to the undoubted proper motion of our
un through space. This, however, may be re-
as certain, that until we know something
ing the laws which regulate the stellar move-
we must regard the magnitude of a star's
as probably an indication of relative proximity.
ely as a man walking at a great distance from us

a star's motion is diminished in proportion to the r's distance from us. When, therefore, it was found t the star Alpha Centauri is moving more rapidly n other stars, this fact, combined with the great tre of the star, led astronomers to suspect that it st be comparatively near to us.

Observations made to determine whether the star ws any sign of an annual change of place corre- nding to the earth's annual orbital motion, were varded by the detection of a very appreciable dis- cement. In fact, owing to the motion of the earth, h year, in a nearly circular orbit 185,000,000 miles diameter, the star Alpha Centauri appears to trace each year a minute oval path on the celestial ere, the greater axis of the oval being equal in gth to about $\frac{1}{900}$th part of the moon's apparent meter.[1]

It follows from this, that in round numbers the tance of Alpha Centauri from us is about twenty llions of millions of miles. The distance of the th from the sun shrinks into insignificance beside s enormous gap. Even Neptune, though circling nd the sun at a distance thirty times vaster than t which separates us from that luminary, is yet atively so much nearer than Alpha Centauri, that un filling the whole orbit of Neptune would apas seen from that star, but about $\frac{1}{900}$th as large sun appears to us.

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[1] It hardly need be mentioned, perhaps, that this motion being eradded to the star's more considerable proper motion, the path ch the star seems really to follow is a looped one, the size of

ow let us consider what dimensions we may assign ha Centauri, on the assumption that the surface is star emits a light as brilliant as that which eds from the photosphere of our own sun. We not neglect the consideration that the star is e—the companion emitting perhaps about one-as much light as the primary.[1] The distance of Centauri is equal to about 230,000 times that separates us from the sun. Therefore, if re-l to the star's distance, the sun would shine with $\frac{1}{2,900,000,000}$th part of his present brilliancy. Now, ing to the most careful estimates of the bril- of Alpha Centauri, the light we receive from star is about $\frac{1}{16,950,000,000}$th of that we receive from un.[2] It follows, therefore, that the star emits three times as much light as the sun; and ore, so far as the emission of light is a criterion , the star may be regarded as considerably larger

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the first edition of this work the smaller star was described ting about one-sixteenth as much light as the primary; and te I remarked that Sir John Herschel, observing the star s 20-feet reflector, thought the secondary brighter than it lly considered, but that, for a comparison of this sort, telescopes seemed to me likely to be on the whole more rthy. He convinced me that my opinion as to the bright- the secondary was erroneous. Hence the change in the e.

is estimate is founded on Sir John Herschel's comparison an our own sun. In fact, reducing the total light the pair by one-seventh, we find that the primary ust still emit nearly three times as much light as the n, and therefore the diameter of the star, as thus timated, would appear to exceed our sun's in the oportion of about 8 to 5.

We have here, then, clear and decisive evidence in vour of the view that among the fixed stars there e orbs which may be regarded as veritable suns orthy to be the ruling centres of schemes as noble the solar system. For we know quite certainly that e greater number of the first magnitude stars are ry much farther from us than Alpha Centauri, with nich, however, they are fairly comparable in brilncy; so that they may be regarded as for the most rt at least equal to that star in size and mass. Sirius d Canopus, indeed, must far surpass Alpha Cenuri. The latter, though more than thrice as bright, hibits no appreciable change of position as the earth rcles round the sun. Sirius, which is more than ır times as bright as Alpha Centauri, shows an nual change of position which certainly does not ceed one-fourth of that star's. It is therefore four nes farther from us than Alpha Centauri, and, did emit no greater amount of light, would appear to ine with but one-sixteenth of that star's lustre. As reality it is four times as bright, the real amount of ht it emits must exceed that of Alpha Centauri less than 64 times, and that of our own sun no cation alone, the diameter of Sirius may be held to exceed that of our sun in the proportion of about 14 to 1, an estimate which assigns to Sirius a diameter of nearly 12,000,000 miles, and a volume 2,688 times as large as the sun's.

But on the other hand, still confining our attention to this method of estimating magnitude, we find reason for believing that many of the visible stars must fall far short of our sun in magnitude. The sixth magnitude double star 61 Cygni, has been found to be nearer to us than Sirius, and about three times as far from us as Alpha Centauri. Now, we may assume that each component sends us about one-hundredth part of the light we receive from Alpha Centauri: it follows that the latter star, if removed to the distance at which 61 Cygni lies from us (when its light would of course be diminished to one-ninth of its present value), would outshine either component of that double star more than 11 times. Hence (on the assumption that brightness is a fair measure of real dimensions), each component has a diameter less than one-third that of Alpha Centauri. We may roughly estimate the volume of each at about $\frac{1}{30}$th of that of the latter star. So that, remembering what has already been shown respecting the relation between Alpha Centauri and our sun, the two suns which form the double star 61 Cygni would each have a diameter equal to about $\frac{17}{30}$ths of the sun's, and a volume equal to about $\frac{2}{11}$ths of his. The sum of their volumes would be therefore about one-third of his; and it will presently appear at a perfectly distinct method of estimation tends to ow that the sum of their masses bears about the me proportion to the sun's mass.

But here at once we have evidence that there is a ery wide range of magnitude among the fixed stars. 'e have seen reason to believe that Sirius is 2,688 mes as large as the sun, while each of the suns rming the double star 61 Cygni would appear to ve a volume less than one-fifth of our sun's, and erefore less than $\frac{1}{13,500}$ths of the volume of Sirius. So at, by considering only three cases, we have found lerably clear evidence of a range of variety in volume, minding us forcibly of that which we recognise in e solar system. We cannot suppose that these three ses, which have been selected at random—so far as e question of volume is concerned—indicate anything xe the real limits within which the fixed stars differ magnitude. So that we may confidently accept, as e most probable conclusion from the evidence before , that the range of real magnitude among the fixed ars is very far greater than Sir W. Herschel was d to anticipate when, nearly a century ago, he began s researches into the sidereal system.

But it is not sufficient that we should thus form an timate of the nature of the fixed stars from the nount of light they send to us. It is desirable—and rtunately it is practicable—to obtain information as the absolute mass or weight of some of the fixed ars, and further, to ascertain of what substances they

may exist. Mere lights, however glorious, or
r wide the sphere within which they displayed
lendours, would not be fit to sway the motions
resembling those which circle around our sun.
uld such lights serve to indicate to the astro-
that, out yonder, myriads of millions of miles
the extreme limits of the solar system, there
aterials suited to form the substance of worlds
ling our own.

eems a strange circumstance that astronomers
be able to form a more exact and trustworthy
e of the weight of certain fixed stars than they
e to form respecting the volume of any of those

us consider the evidence.

ave spoken of the star 61 Cygni as a double
The smaller star shows very clear indications
tal motion around its primary. That the two
ociated together, and not merely seen (as it
y accident), nearly in the same line of view, is
certain, because that peculiarly large proper
already referred to is shared in by both. But
tars may be physically associated, and yet the
e really separating them may enormously exceed
y which they seem to be separated—since the
ning them is not necessarily square to the line
t. The components of the star 61 Cygni have
arefully watched, however, and their motions

parating them is probably about half as large again the distance of Neptune from the sun.

The period of revolution appears to be about 520 ars, which is more than three times as great as the riod of Neptune. Now we know that a planet, ced at a distance from the sun equal to that which parates the components of 61 Cygni, would occupy much less period than 520 years in completing a volution; in fact, its period would be about 300 ars. Hence it follows that the components of 61 gni are attracted together less forcibly than Neptune attracted towards the sun, and therefore that the n of their masses must be less than the sun's mass. is easy to compute the actual proportion, and we d, on doing this, that the two components of 61 gni, taken together, weigh about one-third as much our sun.[1]

The star Alpha Centauri is also a binary system, d though it has not been so systematically observed 61 Cygni, some astronomers believe that its period s been even more satisfactorily determined. Indeed ere are peculiarities in the motion of 61 Cygni ich, without throwing doubt on the general conclusions deduced above, yet suggest that a third (probably aque) orb affects the motions of the other two. From areful comparison of all the observations made in recent times on Alpha Centauri, Mr. Hind has assigned to the components a period of revolution of about eighty-one years, and a mean distance of 13·6 seconds of arc, corresponding to a real distance exceeding the earth's distance from the sun some fifteen times. Since a planet placed at this distance from the sun would occupy less than sixty years in completing a revolution round that body, it follows that the mass of the two components of Alpha Centauri must be less than that of the sun. This result (if the data be considered trustworthy) would indicate a considerable difference between the condition of the star and that of our sun; for we have seen that the star gives out much more light than the sun. However, I believe that many years must elapse before we can regard the period of Alpha Centauri as satisfactorily determined.[1]

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[1] It may be easily shown that if a pair of bodies circling around h other at a certain distance take a certain time T in effecting a olution, while another pair at the same distance take a time t,

Still, we have conclusive evidence in this case, as in that of the star 61 Cygni, that the component stars

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[1] Mr. Powell supplies the most satisfactory elements of the orbit yet given, since he founds his estimate on a more complete series of observations. He assigns to the system a period of 76¼ years, and a mean distance of 20·13 seconds of arc, corresponding to a real distance about 22 times as great as the earth's distance from the sun. A planet at this distance from the sun would occupy about 103 years in completing a revolution. Hence the mass of the two components of Alpha Centauri turns out to be greater than that of the sun—instead of less, as when Mr. Hind's elements were used. This corresponds with the measurement of the star's light, though the disproportion of the masses calculated in this way is not so considerable as it would be if the masses were inferred from the light of Alpha Centauri. By applying the fomrula of the preceding note, it will easily be found that with Mr. Powell's elements the mass of Alpha Centauri (both components) equals about twice that of our sun.

e really bodies of enormous weight, and consequently
ll fitted to sway the motions of families of planets.
e conclude, therefore, that the fixed stars generally
e *suns*, not mere *lights*; and further, we are led to
lieve that there must be a general similarity in the
nditions under which these bodies and our own sun
it light. And thus we are led to recognise other
rs also—though yet unweighed—as massive orbs,
t merely supplying light to other worlds travelling
ound them, but regulating by their attractive in-
ences the orbital motions of their dependent worlds.

But we owe to the revelations of the spectroscope
e complete proof of these matters, besides evidence
other and equally interesting points.

It had long been known that the spectra of the
ed stars present a general resemblance to the solar
ectrum, though of course very much fainter; and
at dark lines can be seen in these spectra, some of
ich correspond with those in the sun's spectrum
ile others seem to be new. So soon as the great
covery effected by Kirchhoff had been announced,
was seen at once that these dark lines in the stellar
ectra afford the means of determining the constitution
the stars. It was only necessary that these lines
ould be identified by their correspondence with the
es belonging to known elements, in order to prove
at these elements exist in the substance of the star.
t although the principle on which researches were
be conducted was sufficiently simple, many diffi-

by Airy, Secchi, and Rutherfurd to solve the n of determining the constitution of the stars by of spectroscopic analysis were unsuccessful; and not until Mr. Huggins and Professor Miller enced their famous series of researches that the m can be said to have been fairly mastered.

en in the hands of these eminent physicists the was difficult and its progress tedious. The er necessary for the successful prosecution of so e a method of inquiry does not often prevail in riable climate. The comparison between the nes in the stellar spectra and the bright lines ing to various elements was not only a delicate borious task, but was singularly painful to the And other difficulties into which I have not o enter here had to be encountered and over-

t undeterred by these difficulties, the two physpersevered in their researches, and were rewarded ults so interesting and important that their dismay be said to constitute the most remarkable the history of sidereal research since the coma of the star-gaugings of the elder Herschel.

o bright stars, Betelgeux, the leading brilliant of and Aldebaran, the chief star of Taurus, were ned with special care. Mr. Huggins remarks ne spectra of these stars are as rich in lines as the pectrum itself. The places of no less than eighty ces assigned to them in the spectrum of Alde-ran.

With respect to the former spectrum, Mr. Huggins narks that it is most complex and remarkable. rong groups of lines are visible, especially in the l, the green, and the blue portions'; a peculiarity, it y be remarked in passing, which serves to account the well-marked orange colour of this star.

Now here already we have very decided evidence as the nature of the star; since the very fact that its ctrum presents the same general appearance as the ar spectrum proves conclusively that the star is an andescent body, whose light comes to us through tain vapours corresponding to those which surround sun. Nor should we be able to regard the star as er than a sun, even though none of the elements own to us should appear to be present in its sub-nce or in the vapours surrounding it. For clearly have no reason for believing that worlds can be med out of those elements only with which we are uainted, unless we find as we proceed that those ments actually do compose the suns which form the ereal system. Of course, if this shall appear to be case, our conclusions respecting the nature of the rs will be very much strengthened.

Now, when Professor Miller and Mr. Huggins com-ed the lines in the spectrum of Betelgeux with bright lines of certain terrestrial elements, they nd that some of these elements do actually exist sium, calcium, iron, and bismuth are present in reux. The lines of hydrogen, which are so well d in the solar spectrum, are not seen in the spec- f Betelgeux. We are not to conclude from this ydrogen does not exist in the composition of the We know that certain parts of the solar disc, examined with the spectroscope, do not at all exhibit the hydrogen lines, or may even present as bright instead of dark lines. It may well be n Betelgeux hydrogen exists under such condi- hat the amount of light it sends forth is nearly lent to the amount it absorbs, in which case its teristic lines would not be easily discernible. In t is important to notice generally that while can be no mistaking the positive evidence ed by the spectroscope as to the existence of lement in sun or star, the negative evidence ed by the absence of particular lines is not to arded as decisive.

the case of Aldebaran the two physicists were o establish the existence of sodium, magnesium, gen, cæsium, iron, bismuth, tellurium, antimony, ercury in the vapours surrounding the star.

sides these stars fifty others were examined. brilliant Sirius exhibits a spectrum of great y, though the low altitude which this star attains latitudes renders the observation of the finer exceedingly difficult. But the two physicists

All the stars examined exhibit spectra crossed by merous lines, and in a great number of the spectra es belonging to known terrestrial elements were tected.

And now let us consider the general bearing of ese interesting discoveries.

In the first place, we are forced to recognise in e stars *real suns*, not mere lights. Doubtless Whe- ll did well in pointing out that astronomers had right to regard the stars as suns until they had me evidence that these orbs resemble the sun in her respects than in size, mass, or luminosity. And in his day it appeared altogether unlikely that such idence should be obtained, a real limit seemed placed the speculations which men might form as to the istence of other planetary systems besides those cling around the sun.

But now we have precisely that evidence which hewell required. We see that the stars are consti- ted in the same general way as the sun, and that ther they even contain elements identical with those ich exist in his substance. There is not indeed in ery case, perhaps there may not be in any case, an act identity of composition between the stars and our n, or between star and star. But this was no more to ve been looked for than an exact identity of physical bitudes amongst the members of the solar system. at general resemblance of structure which indicates general resemblance in the purposes which the celest when we compare the stars either with our sun each other.

ave already spoken of the conclusions to be from the existence of the same materials in the nce of the sun that exist around us on this earth. shown that we are compelled to regard this l resemblance of structure as sufficient to prove he other planets resemble the earth, since we no reason to believe that our earth bears an ionally close resemblance to the sun as respects ements of which she is composed.

ce, then, we have reason to believe that all the s which circle around the sun are constituted of me materials which exist in his substance, though materials are not necessarily nor probably com- in the same proportions throughout the solar , we have every reason which analogy can give believing that the planets circling around Betel- r Aldebaran are constituted of the same materials exist in the substance of their central luminary.

us we are led to a number of interesting con- s even respecting orbs which no telescope that an construct is likely to reveal to his scrutiny. istence of such elements as sodium or calcium e other worlds suggests the probable existence familiar compounds of these metals—soda, salt, nd the rest. Again, the existence of iron and netals of the same class carries our minds to the

ognise that the orbs circling around those dis-
nt suns are not merely the abode of life, but
at intelligent creatures, capable of applying these
tals to useful purposes, may exist in those worlds.
e need not conclude, indeed, that at the present
ment every one of those worlds is peopled with in-
ligent beings, because we have good reason for be-
ving that throughout an enormous proportion of the
ne during which our earth has existed as a world no
elligent use has been made of the supplies of metal
isting in her substance. But that at some time or
ner those worlds have been or will be the abode of
elligent creatures seems to be a conclusion very
rly deducible from what we now know of their
bable structure.

But secondly, apart from the information afforded
the spectroscope respecting the materials of which
e stars are composed, the nature of the stellar spectra
ves to prove most conclusively that the stars, besides
pplying light to the worlds which circle around them,
liate heat also to them. Even if we were not cer-
n that elements which are only vaporised at a very
gh temperature exist in the vaporous envelopes of
e stars, yet the very nature of the light sent out by
e stars indicates that these orbs are incandescent
rough intensity of heat. When we find that the
ectrum of the moon's light resembles the solar spec-
um, we do not indeed conclude that the moon is as
ensely heated as the sun, because we know that the

ous bodies like the stars, we can conclude from
ery nature of their spectra that these orbs are
ely heated. Of course we are rendered abso-
certain of this when we find that iron and other
exist in the form of vapour in the stellar atmo-
s.

e vast supplies of heat thus emitted by the stars
nly suggest the conclusion that there must be
around these orbs for which those heat-supplies
tended, but point to the existence in those
of the various forms of force into which heat
be transmuted. We know that the sun's heat
d upon our earth is stored up in vegetable
nimal forms of life ; is present in all the phe-
na of nature—in winds, and clouds, and rain.
under and lightning, storm and hail ; and that
he works of man are performed by virtue of the
heat-supplies. Thus the fact that the stars send
heat to the worlds which circle around them
sts at once the thought that on those worlds
must exist vegetable and animal forms of life ;
atural phenomena, such as we are familiar with
e to the solar heat, must be produced in those
s by the heat of their central sun; and that
such as those which man undertakes on earth
ks in which intelligent creatures use Nature's
s to master Nature to their purposes—may go
the worlds which circle around Aldebaran and

Recently it has even been found possible to render ie stellar heat sensible to terrestrial observation—by ethods which need not here be inquired into. Nay, ie task of measuring the amount of heat received om certain stars has not been thought too difficult. r. Stone, making use of the powers of the great juatorial of the Greenwich Observatory, and inge- ously overcoming the numerous difficulties which ist in a research of such exceeding delicacy, has rived at the conclusion that Arcturus sends us about much heat as would be received from a three-inch ibe full of boiling water, and placed at a distance 383 yards. Vega, which shines, according to Sir Herschel, with about two-thirds the light of Arc- rus, gives out about the same proportionate amount heat.[1] But in other instances the heat-giving wer of a star has not been found proportional to the nount of light it emits.

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[1] Although these results cannot yet be regarded as numerically act, it may be interesting to consider the amount of heat given t by Arcturus in relation to the light sent us by this star, the re so as this star seems (from the nature of its spectrum) to re- nble the sun very closely in constitution.

The light sent to us by Arcturus is equal to about three-fourths that supplied by Alpha Centauri, or about $\frac{1}{21,000,000,000}$th part of the bt we receive from the sun. Now Mr. Stone estimates the direct ating effect of Arcturus at 0°·00,000,127 Fahrenheit, making e allowance for the effect of the object-glass in concentrating d absorbing the heat. It will be seen at once that, according to s estimate, the heating power of Arcturus bears a very much eater proportion to that of the sun than the respective light- ving powers of the luminaries bear to each other. This seems throw some doubt on the correctness of the estimate either of

The variation of many fixed stars in lustre at once forms a new bond of association between the stars and the sun—which we have seen to be in reality a variable star—and suggests interesting inquiries as to the existence of variation in the emission of heat. Some of the stellar variations of light are so much more marked than those noticed in the case of our own sun that we can scarcely conceive how creatures resembling any with which we are acquainted could endure the effects of correspondingly important variations of heat; nay, in some instances we seem compelled to withhold our belief in the existence of habitable systems around certain fixed stars. The star Eta Argûs, for example, which sometimes blazes out with a light surpassing that of any of the stars in the northern hemisphere, while at other times it falls to the sixth magnitude, can hardly be regarded as fit to be the centre of a system of worlds. I pass over such variable stars as the one which recently blazed out in the Northern Crown, because in a case of this sort the star may be regarded as really a small orb, and its sudden lustre as due to some exceptional occurrence, leading (as the spectrum of the star seemed to show) to a temporary conflagration. But Eta Argûs, and Mira Ceti seem to belong to a different category altogether, since it is probable as respects the former, and certain as respects the latter, that their appearance as stars of the leading magnitudes is not accidental, but part of a systematic series of changes.

It remains only to be mentioned that, besides light d heat, the stars emit actinic rays. This is proved cisively by the fact that the stars can be made to otograph themselves. It has been found, however, at the actinic power of a star, like its heat-giving wer, is not by any means proportional to the star's ht. So that in this respect, as in the material nstitution of the stars, we find specific varieties even id those very features which indicate most strikingly e general resemblance which exists between the suns nstituting the sidereal system.

To sum up what we have learned so far from the idy of the starry heavens—we see that, besides our n, there are myriads of other suns in the immensity space; that these suns are large and massive bodies, pable of swaying by their attraction systems of rlds as important as those which circle around the n; that these suns are formed of elements similar to ose which constitute our own sun, so that the worlds ich circle round them may be regarded as in all obability similar in constitution to this earth; and at from these suns all the forms of force which we ow to be necessary to the existence of organised ings on our earth are abundantly emitted. It seems asonable to conclude that these suns are girt round dependent systems of worlds. Though we cannot, in the case of the solar system, actually see such rlds, yet the mind presents them before us, various size, various in structure, infinitely various in their

CHAPTER XI.

OF MINOR STARS, AND OF THE DISTRIBUTION OF STARS IN SPACE.

s been so long a received opinion that a general
mity of magnitude and distribution characterises
ellar system that it is with some diffidence I
re to express a different view. And here let me
e misunderstood. I am fully sensible that it is
n certain popular treatises of astronomy that a
in anything like a real uniformity of structure
e sidereal system is attributed to astronomers of
rity. It is not any such imaginary theory that
e now to deal with, however ; but with opinions
have found a place in the works of astronomers
whom I very unwillingly differ.

propose to exhibit the reasons which have led me
eve that, so far from knowing the real figure of
dereal system, astronomers have not been able to
rate to its limits in *any* direction ; that leading
such as those discussed in the preceding chapter,
stributed throughout space to the very farthest

e arranged in groups and clustering aggregations, in
eams and whorls and spirals, in a manner altogether
o complex for us to hope to interpret; and that in
ese aggregations stars of all degrees of real magni-
de are mixed up, from suns as large as Sirius down
orbs which may be smaller than any of the primary
nets of the solar system.

Let us consider step by step the evidence we have
these points.

We know, from the existence of double, triple, and
ltiple stars, in which the components are often very
equal in splendour, that combinations of stars exist
which one or two may be suns like our own, while
e rest, or some of the rest, are relatively minute.
is, however, has of course long been known; and it
only as a preliminary step in the investigation that
ere advance so trite an instance.

Next let us consider such star-clusters as contain
s of the eighth or ninth magnitude, besides a mul-
ude of minute stars. These clusters must of course
regarded as lying within the sidereal system, since
external galaxies could reasonably be supposed to
tain orbs so infinitely transcending even Sirius in
gnitude as to shine from beyond the enormous gap
arating us from such galaxies with a light exceed-
that derived from many stars within the sidereal
tem. Now, regarding these clusters as forming
t and parcel of the sidereal system, we find in the
stence of multitudes of minute orbs within their

ciated stars is to be regarded as a feature of parts, at any rate, of our galaxy ; and we shall re be the less surprised if we should find reason eving that it is a *characteristic peculiarity* of actic system.

with regard to the nebulæ (resolvable and irre- e), and their claim to be regarded as external s, I shall have much to say farther on ; but I nark in passing that we have precisely the same for believing that many of these objects lie the range of the solar system, as have been considered in the case of star-clusters. Their ent stars, to be visible at all, *must* fall within ge of distance which astronomers have assigned boundaries of the galaxy, since some stars even this range cease to be separately visible in the owerful telescopes man has yet constructed. So en in these objects we see a few or many dis- ars, and a mass of nebulous light which we judge eed from an indefinitely large number of minute e again have very decided evidence of the fact one and the same region of the sidereal system ay exist leading stars (so to speak) and innu- e stars relatively minute.

h considerations such as these (and I might add thers) to guide us, let us proceed to examine chings of the Milky Way itself, that we may ether that wonderful zone indeed represents, as

parately, in comparison with our sun or Sirius, Alde-
ran or Betelgeux, Vega or Arcturus.

The star-gauging of Sir W. Herschel, interpreted
cording to his hypothesis of stellar distribution,
nted to an extension of the Milky Way laterally
a distance exceeding some eighty times that which
parates us from the first-magnitude stars. So that,
garding sixth-magnitude stars as on the average
out ten times as far from us as those of the first
gnitude (the usual estimate), we see that the outer-
st parts of the galaxy must lie (according to Sir W.
rschel's theory) about eight times as far from us as
sphere of the sixth-magnitude stars. Now Sir
nn Herschel was led by his observations of the
thern heavens to so far modify his father's theory
to describe the Milky Way as probably shaped like
lat ring, the stars down to the tenth magnitude
ng in a sense dissociated from the ring, while he
garded the probable distance of the outermost limits
the ring as 750 times instead of but 80 times the
an distance of the first-magnitude stars. This
ference of opinion, it may be remarked, though
viously not surprising when we consider the enor-
us difficulty of the problem presented by the sidereal
tem, is yet sufficient to indicate the probability that
important error has been made in the hypothesis
ich underlies the accepted theories respecting the
axy. But, be this as it may, in regarding the Milky
y as shaped like a flat ring (cloven through one-

bles generally the space between the dark con-
c circles in the accompanying figure (in which

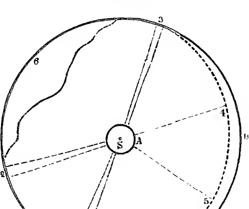


Fig. 2.—The Galactic Cloven Flat Ring (plan).

quals eight times SA), I have not adopted a
ure which *exaggerates* the difficulties presented

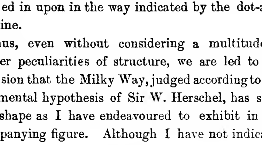
Fig. 3.—The Galactic Cloven Flat Ring (section).

e disc or ring theory of the Milky Way. The
section would be somewhat as shown in fig. 3.

erschel's theory that the Milky Way forms a cloven se, let us consider whether any peculiarities of the ilky Way seem to oppose themselves to this inter- etation of its structure.

In the first place, then, there is a gap or rift ex- nding right across the single part of the Milky Way the constellation Argo; so that we must conceive at from S towards 1, in fig. 2, the flat ring is broken rough by some such rift as is indicated by the broken es in that direction. Next there is, in the constella- n Crux, a pear-shaped vacuity of considerable size, d bounded by well defined edges; so that we must nceive that from S towards 2 (fig. 2) the flat ring tunnelled through by some such passage as is indi- ed by the dotted lines in that direction. A similar nnelling, but of different cross-section, must exist in ection S 3 (as shown by the dotted lines) to account the dark gap in the constellation Cygnus. Next, ere the Milky Way is double, a large portion of one nch is discontinuous, so that the upper part of the uble portion of the ring in fig. 2 must be supposed moved between the broken lines from S to 4 and 5. er the so-called double stream there are in places ange convolutions, in others numerous branching d interlacing streams, whose complexity indeed ies description; so that the portion 3 B 2 of the g must be supposed corrugated in the strangest y, and further to throw out plane and curved sheets stars presented tangentially towards S. Lastly, ls 6, so that here we must conceive its figure ed in upon in the way indicated by the dot-and-ine.

us, even without considering a multitude of er peculiarities of structure, we are led to the sion that the Milky Way, judged according to the mental hypothesis of Sir W. Herschel, has some shape as I have endeavoured to exhibit in the panying figure. Although I have not indicated



. 4.—The Galactic Flat Ring modified in accordance with the observed peculiarities of the Milky Way.

he corrugations of the ring, nor a tithe of the s overlapping layers which would be required to ıt for the appearance of the Milky Way between urus and Ophiuchus, yet the deduced figure is means inviting in its simplicity. It is, however, tely certain that the sidereal system, as far as its densely aggregated star-regions are concerned, Now, in turning our thoughts to the recognition of nore simple explanation of observed appearances, it ll be well that we should consider some peculiarities the Milky Way which we have not yet attended to. the first place, I would invite attention to a pecu- rity observed by Sir John Herschel in different rts of the galaxy—the fact, namely, that in places e edge of the Milky Way is quite sharply defined. ie half of a telescopic field of view may be quite ar of stars, or show only a few straggling orbs, iile the other half presents what has been called a Iilky Way field'—that is, a region profusely sprinkled th stars, the boundary between the two portions ing well defined. When we see that a cluster of jects presents a well-defined edge, what conclusion we draw as to the position of the object? Is it not such a case absolutely certain that the distance of e cluster enormously exceeds the distance between component parts—or in other words, that the server is far outside the cluster? Many instances ll at once suggest themselves to the reader in illus- tion of this remark.

We conclude, then, that these portions of the Milky ay, at any rate, whether they be regarded as projec- ons or nodules, are definite clustering aggregations ry far removed from us. Other parts of the Milky ay *may* also be removed bodily, so to speak, to ormous distances, because a cluster which has not lefinite edge may be as far removed as one which

Next let us consider what opinion we may found he existence of dark regions in the Milky Way; here I refer not merely to such large and obvious ities as the Coal-sack in Crux or the oval opening ygnus, but also to small openings, in which, though occur even in rich regions of the Milky Way, e is not, according to Sir W. Herschel's descrip- even a telescopic star to be seen.

Judged apart from preconceived opinions, such open- as these, according to all laws of probability, ate that the portion of the Milky Way in which occur has not a very great lateral extension. To n for a moment to fig. 2, it will be seen at once that perture extending laterally through a star system haped must have a particular direction and be ectly straight in order to be visible to observers ed, as we are supposed to be, in the central open- It is altogether improbable that one such open- should exist by accident, and absolutely impossible many should.[1] We are forced, therefore, to infer , instead of the enormous lateral extension assigned he Milky Way, the galaxy has in these places ainly, and elsewhere probably, a lateral extension greatly exceeding its depth.

t is further to be noted that the lucid stars over

Sir John Herschel distinctly indicated this inference, as he many other matters which make strongly against the received y of the sidereal system. Nor was he unconscious of their og. Apparently unwilling to press them to their full extent, he zone of the heavens which is occupied by the galaxy show a very decided preference for the parts of that zone which are actually traversed by the Milky Way. For instance, we find no stars above the fifth magnitude, and very few of these in the Coal-sacks, or n the rift which crosses the Milky Way in Argo; or, again, in the space which lies between the two branches where the Milky Way is double. If this is an accident t is a very extraordinary one, especially when it is remembered that the region where it occurs is the very part of the heavens where stars of all magnitudes may be expected to be most profusely distributed; that the spaces thus left vacant form no inconsiderable aliquot part of that zone; and that, according to the accepted theory, there is no reason for expecting any peculiarity of the sort.

Thus, again, setting aside preconceived opinions, and judging only according to the evidence, we seem ed to regard the coincidence as not accidental, but as indicating that there really is a very close association between the bright stars and those small stars forming the milky light, which, according to the accepted theory, lie so many times farther from us.

But this opinion is absolutely forced upon us when we apply a rigid process of examination to the evidence we have respecting the distribution of the lucid stars over the galactic zone. So far as I am aware, this has not hitherto been attempted. Indeed, independently of the fact that I have not met with any reference to n inquiry, although I have had occasion to study arefully all the works bearing on the subject, I nfident that the examination I refer to has never en attempted, because I am sure that if it had, sult must have been the adoption of views alto- different from those at present accepted. I shall ccasion, farther on, to exhibit the method by the following results have been obtained, and re I content myself in this place with simply them:—

e Milky Way covers $\frac{21}{220}$ths of the whole heavens, the gaps and lacunæ in the Milky Way cover 1–62nd part. In the Milky Way there are 1,115 tars; in the gaps and lacunæ only 20. So that whole heavens were as richly covered with lucid s the Milky Way, there would be 11,681 stars to the naked eye, instead of the 5,850 actually But if the whole heavens were no more richly with stars than the gaps and lacunæ in the Way, there would be but 1,240 lucid stars. *ilky Way is, in fine, no less than nine times as strewn with lucid stars as its gaps and lacunæ, as according to the accepted views no such arities are to be looked for in the distribu- f lucid stars over the galactic zone.*

e have here a statistical fact which *must* be ted for in forming a theory of the sidereal . I have, indeed, no hesitation in saying that it ribe it to mere chance distribution.[1] Where, then, the cause, unless we accept the obvious and simple lanation that the Milky Way *seems* to be thus ociated with lucid stars because it *is* associated with em—that in place of being, as has so long been posed, a congeries of suns many times more distant n the lucid stars, it is formed of myriads of relaely minute orbs compared with which those lucid rs are as the giant planets of our solar system comed with the asteroids?

It is very clear, then, what views we are to form pecting the Milky Way. If the galaxy is, *first*, clustering aggregation separated from us by an erval comparatively clear of small stars; *secondly*, shaped that the cross-section of the stream is everyere not far from a roughly circular figure; and *rdly*, associated very closely with the bright stars n in the same field of view, then must its struce be somewhat as shown in fig. 5, in which the cs represent lucid stars (very much exaggerated course in size), while the fine dotting represents spiral of relatively minute stars, clustering along spiral group of leading stars. It will be seen once how, to an observer placed at S, the various tures of the Milky Way can be accounted for this figure. Towards *a* would lie the gap in

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[1] If the clouds of a summer sky arrayed themselves in rank and so as exactly to correspond to the panes of the window through ch I view them as I write, I should not regard the coincidence

Argo; towards *b* two branches, one faint, and in part evanescent through vastness of distance, the other forming the brightest part of the spiral; towards *d* the projection in Cepheus; towards *e* the faint part of the Milky Way in Gemini and Monoceros. The Coal-sacks would be simply accounted for by conceiving that branches seen towards the same general direction, but at different distances, do not lie in the same general plane, and so may appear to interlace upon the heavens. We are not only justified in supposing this, but forced to do so by the way in which the stream of milky light is observed to *meander* on its course athwart the heavens. The branching extensions serve very well to account for the appearance of the Milky Way between Centaurus and Ophiuchus, where the interlacing branches and the strange convolutions and clustering aggregations described by Sir John Herschel are chiefly gathered.

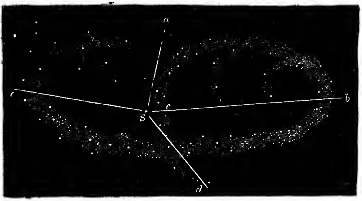

Fig. 5.—The Milky Way regarded as a Spiral.

I would not have it understood, however, that I at l insist on the general shape of the spiral shown fig. 5. On the contrary, that curve is only one t of several which might fairly account for the served appearance of the Milky Way; and I have ten felt inclined to doubt whether a single spiral of is sort is in reality the best way of accounting for e observed appearance of the galactic zone. What do insist upon as most obviously forced upon us the evidence is that (1) the apparent streams rmed by the Milky Way upon the heavens indicate the existence of real streams in space; and (2) at the lucid stars seen on the stream are really sociated with the telescopic stars which form, so to eak, the body of the stream. Whether that stream rm a single spiral or several, or *whether, instead of irals, there may not be a number of streams of nall stars, placed at different distances from us, and ing in all directions round the medial plane of the laxy, but more or less tilted to that plane (the sun ot lying within any one of the streams*), are questions hich can only be resolved by the systematic scrutiny this wonderful zone.

The chief points to be noticed among the considerations flowing from these general views are these:—

In the first place, the only marked difference between the stars of the leading magnitudes (say the st ten) lying in the galactic zone, and those lying thout it, consists in the fact that the former are sociated with countless multitudes of smaller stars,

o many of them. We shall see presently that the
-galactic stars *are* associated, and in a very in-
e manner, with groups of very minute stars—of
so minute indeed as not to be separately dis-
ble—so that astronomers have been led to regard
groups as external galaxies. But except in one
n, we do not find outside the galactic zone any
rances reminding us of the aspect of the Milky
itself. In that region lie the two Magellanic
ls, resembling the Milky Way in their general
rance, but seen, when placed under telescopic
ny, to differ from it in this, that among the
te stars which cause the milky light are numbers
bulæ, of classes not found commonly, if at all, in
alactic zone.

n the second place, we must conclude that un-
ed millions of stars exist which are very minute
d in comparison with those which we have been
o regard as suns. That these relatively minute
may be absolutely large—far larger, for instance,
our own earth—may indeed be accepted as certain.
t is difficult to believe that they subserve pur-
similar to those of our own sun. One cannot
ee that orbs such as these would not have that
anence of character, as sources of heat-supply,
would seem to be necessary in the case of a real
We know, indeed, that among the small stars
e Milky Way there is a proneness to irregular

od of the Milky Way, with scarcely an exception, ose temporary stars have blazed out which have med a subject of such perplexity to the thoughtful ronomer. Under what conditions the small orbs in e Milky Way actually exist, whether clusters of em will eventually segregate from their neighbours to m suns, or whether, after long voyaging in spiral and ntorted paths under the varying influences of the ractions of leading stars, these minute orbs will, for e most part, be forced to settle down as attendants und the major ones, it is as yet altogether impossible judge. It may be that they bear the same sort relation to the leading stars that certain cometic and teoric families, referred to in Chapter IX., bear to e major planets of the solar system, not being in any e absolutely dependent on any large star, but yet urning in cycles, which must be measured by llions of æons, to temporary dependence on one sun er another; until in the course of time, under the ion of processes somewhat resembling those I have nceived to take place in the formation of the solar tem, the conditions under which they move will ve become so far altered as to lead to the breaking of the Milky Way into distinct systems. Indeed, Sir William Herschel was led by other considera- ns long since to point out, there are signs in parts the Milky Way which would seem to indicate that eral such systems have already reached an advanced ge of development.

ble from the circumstances I have dwelt upon uming my interpretation of them to be in the main ect) is this, that we can no longer suppose we in any direction pierced to the limits of the real system. So long as a general approach to ormity of distribution was understood to prevail in that system, there was a ready means of determing when the telescopist had reached in any given ction the limits of the system. To use the words rofessor Nichol, 'When an eye is directed towards olonged bed of stars, there is no reason to fancy it has reached the termination of that stratum so as there appears behind the luminaries which are vidually seen any milky or nebulous light; such probably arising always from the blended rays moter masses. But if, after struggling long with bulous ground, we obtain a telescope that gives us tional light with *a perfectly black sky*, we then have y reason the circumstances can furnish on behalf he supposition that at length we have pierced ugh the stratum; a probability, indeed, which can converted into certainty in only one way—viz no increase of orbs follows on the application of ll larger instrument.' Sir John Herschel has exsed a similar view, and there can, indeed, be no bt that, adopting the fundamental hypothesis on h accepted views are founded, the test above ribed is an absolutely certain one.

ound' (to use Professor Nichol's striking but some- hat incorrect expression), we have in reality only en searching with more and more minuteness into a efinite cluster or stream of stars, we can no longer me to the conclusion he has insisted upon. We ve reached the limits of minuteness which the stars the cluster or stream attain to; we have learned rhaps all that we can learn about that cluster or ream; but we can no more be said to have reached e limits of the sidereal system in that direction than can be said to have reached the outermost bounds the universe in the direction of the cluster in ercules, when that magnificent object has been oroughly resolved with the telescope.

Here, then, if I have seemed to narrow the limits the sidereal system by bringing the star-myriads of e Milky Way, which had been regarded as many nes farther from us than the lucid stars, into direct sociation with these luminaries, I make amends by inting out that in all probability the limits of the dereal system lie far beyond the range of the most werful telescopes man has yet constructed. In fact, ere is here a somewhat singular interchange of posi- on between the new and the accepted theories. Ac- rding to the views usually accepted, the small stars the Milky Way are really as large, on the average, the lucid stars; whereas, according to my views, they e relatively minute. But according to the accepted eories, the scattered stars of very low magnitude in tively minute, since it has been rendered certain, according to those theories, that the limits of the sidereal system are relatively close in this direction, and we cannot suppose these stars to lie beyond those limits (as they must do, if really large). Now, according to my views, there is nothing to prevent these minute stars from including among their number orbs as vast as Sirius, or many times vaster. Nay, even within the galactic zone itself there are stars to which my theory gives as noble proportions as the accepted views. For in the southern Coal-sack there are minute telescopic stars, as Sir John Herschel tells us, and these orbs, according to the accepted views, must be regarded as belonging to the galactic circle, though inexplicably segregated from their fellows. According to the views I have been led to form, many of these telescopic stars must be regarded as suns lying far beyond the galactic spiral, or perhaps associated with outer whorls of this spiral which no telescope made by man can ever reveal to us.

And this leads me to consider two phenomena which are altogether inexplicable, I conceive, on any theory except mine.

The first is the existence of excessively faint streams of light—star-streams, doubtless, though the components are not separately visible—in certain regions of the heavens. Sir John Herschel, who detected this strange phenomenon, speaks of the streams as so very faint that the idea of illusion has continually arisen subsequently; yet he dwells far too clearly on the charac-

stics of the phenomenon for any doubt to remain
o its reality. The faintest possible stippling of the
d of view—the minute points of light being obviously
e, though it was impossible to see them individually
mottling which moved with the stars as he moved
tube to and fro, such are the terms in which Sir
n Herschel speaks of this interesting phenomenon.

Now no doubt whatever can exist that if these
t streams really belong to the sidereal system they
left altogether unaccounted for by the ordinary
ws respecting the structure of that system. There
o continuity between the stars composing them and
n the minutest telescopic stars visible in the same
eral direction; so that a vast void must separate
m from the outermost of those telescopic stars. Ac-
ding to my theory, they probably belong to outlying
orls of the spiral galaxy, and the telescopic stars
n upon them bear the same relation to them that
lucid stars bear to the Milky Way.

The second point is perhaps even more striking. In
tain directions Sir John Herschel recognised the
stence of two or more distinctly marked classes of
rs, as though, he said, definite sets of stars, sepa-
ed by comparatively void intervals, lay in those
ections. It is clear that this association of the
rs into sets is as distinctly opposed to the views
inarily accepted as it is obviously an arrangement
be expected according to my theory of the constitu-
n of the sidereal system.

lucid stars in order to find evidence of such association. Amazing and incredible as it may at first sight appear, those orbs which have been visible during so many thousands of years before the telescope was invented, the stars which Hevelius and Ptolemy could chart and catalogue, have been teaching men with unmistakable clearness a lesson which hitherto has been persistently neglected.

It had long since occurred to me that the lucid stars are not spread over the heavens with that general approach to uniformity required by the accepted theories. In constructing my gnomonic charts of the heavens, though these include only the stars of the first five orders of magnitude, I recognised clear traces of the existence of star-streams and star-reticulations, rich regions and barren spaces, which the laws of probability would not permit me to regard as due to chance-distribution.[1]

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[1] I tried the experiment of distributing 2,000 points at random over a square surface. It is not quite so easy as it might at first be thought to secure a perfectly random distribution. The plan I adopted was the following. Taking a book full of numerals (I used a table of logarithms), and opening it at random, I brought the point of a pencil down on the open page. Whatever numeral the pencil-point fell nearest to, I entered in a long list of numerals formed on this plan. Then dividing the sides of my square into 100 parts, and the square itself into 10,000 small squares, I took the numerals in sets of four to indicate the places of a number of dots. Thus, supposing the first four numerals to be 2371, I took that small square which was the twenty-third from one side of the large square and the seventy-first from an adjacent side, and marked a dot in that square. Doing this for 2,000 dots I had a perfectly random distribution. No well-marked streams, reticulations, vacuities, or rich regions could be recognised in the result

But while my larger atlas was in progress this nion grew into conviction. In some of the maps the reness of certain regions contrasted so strangely with richness of others as to give an unfinished appearce to the work. I determined that as soon as I had sure I would combine in two large maps of hemispheres the twelve maps of my atlas, in order to see at the real relations might be which were only tially indicated in maps covering but a tenth part of heavens.[1] I selected for this purpose a mode of jection described in my 'Hand-book of the Stars,' first suggested, I have since found, by Sir John rschel. It represents equal areas on the celestial here by equal areas *in plano*; so that, though there considerable distortion, the real relative richness of 'erent regions of the stellar heavens is accurately resented. The accompanying large plate represents eduction of the maps thus constructed.

[leave the exhibition of minor peculiarities of llar distribution — star-streams, star-reticulations, r-clusters, and so on—to the maps themselves, which l, I think, be found to well repay careful study. But pplied to the original maps a further process of intigation in order to deduce the real characteristics of rich and barren regions I had noticed while con-

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nsider, too, that where so many dots were marked in, one trial as good as a large number.

[1] The maps of my atlas overlap each of the twelve, including a h part of the celestial sphere. The reader may perhaps be sured that the peculiarities I refer to should not have been noticed le other star atlases were constructed. But the great distortion

structing the large atlas. The plan I adopted was sufficiently simple. I cut out the portions of the map which seemed richly or sparsely dotted with stars, and weighed the paper. The relative weights of different portions gave me the relative areas, and thus it was only necessary to count the number of stars in order to determine the relative richness of stellar distribution.

The regions I selected for special examination by this method were the following: –

1. A nearly circular region in the northern heavens surrounding the projection of the Milky Way towards the North Pole, and having a radius of about one-fifth of the map's diameter. I call this *the richest northern region.*

2. A much larger region, including the last, and occupying the middle of the northern map. I call this the *rich central northern region.*

3. A large circular region, occupying the middle of the southern map. I call this the *rich central southern region.*

4. A somewhat triangular region, included within the last, and occupying the upper right-hand part of the southern map (between Sirius, Canopus, and the constellation Crux). I call this *the richest southern region.*

5–6. The remaining, or outer, parts of the northern and southern maps.

7–8. Two very barren regions bordering on the rich northern central region—one towards the lower half of the northern map, the other towards the per half. I call these *the poorer northern regions* *nd* II.

9–10. Two corresponding southern regions, one upying the upper right-hand quadrant of the, thern map, the other occupying the lower quadrant the same side. These I call *the poorer southern ions* I. *and* II.

Lastly, I take the northern and southern portions of Milky Way, and the gaps and lacunæ in the Milky y.

Having selected these regions for comparison,[1] and plied to them separately 'the scissors and balance' t, I have deduced the following results:—

Name of Region	Area (Area of hemisphere, as 1)	Number of lucid stars	Richness (Average = 5,850)
ORTHERN—			
Milky Way . . .	$\frac{1}{11}$	497	9,940
Richest Region . .	$\frac{3}{22}$	622	9,050
Rich Central do. . .	$\frac{5}{11}$	1,420	6,248
Outer do. . . .	$\frac{6}{11}$	1,070	3,923
Poor do. (I.) . . .	$\frac{3}{22}$	201	2,948
Do. do. (II.) . . .	$\frac{3}{22}$	175	2,567
aps in Milky Way . .	$\frac{1}{62}$	20	1,240
OUTHERN—			
Poor Region (I.) . .	$\frac{3}{22}$	161	2,361
Do. do. (II.) .	$\frac{3}{22}$	216	3,198
Outer do. . . .	$\frac{1}{2}$	893	3,572
Rich Central do. .	$\frac{1}{2}$	2,467	9,868
Richest do. . . .	$\frac{3}{22}$	895	13,126
Milky Way . .	$\frac{1}{10}$	618	13,596
lky Way as a whole .	$\frac{21}{220}$ths of sphere	1,115	11,681

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[1] There is some room for choice in taking the boundaries of

But surprising as these results may seem, the question whether such peculiarities of stellar arrangement may not be regarded as due to chance-distribution remains to be considered.

It has been so often urged that amongst a very large number of stars such peculiarities might be looked for that many will be disposed to dispute the assertion that *uniformity, not peculiarity* of distribution, is to be expected among a large number of points spread over any surface according to true chance-distribution. Yet so it is. The laws of probability tell us that whereas among a few such points peculiarities need not surprise us, uniformity of distribution will inevitably appear where there are many points, unless some special law is in operation to prevent such a result.[1]

To illustrate the amazing weight of probability in favour of the existence of laws of aggregation and segregation among the lucid stars, I will state the result of a process of calculation I have applied (in accordance with the recognised laws for determining probabilities) to the statistical relations presented by the two rich regions in the northern and southern hemispheres:—

The vast scale of the universe of the nebulæ (or, as it has been called, the *universe of universes*), as conceived by Sir W. Herschel, is well known. *Now, the probability that the observed relation results from chance-distribution is many millions of times less than the chance of drawing one particular grain, smaller many million-fold than the minutest object visible in the most powerful microscope and lying within a space compactly filled with similar grains, and large enough to enclose many millions of the universes of universes.*

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[1] As a familiar illustration of the law of probabilities in question, we may take the case of tossing a coin. If a coin be tossed six times, there will be nothing very surprising in the recurrence of 'head' (say) four, five, or even six times—that is, if two-thirds, five-sixths, or the whole of the series of results are of one kind. But if we calculate the chance that in six thousand tossings there should be so many as four thousand results of one kind, we find it so minute that the concurrent testimony of all mankind could never make it credible that such an event had happened. The probability is the same as that referred to in the text a few lines further on.

The probability that the more remarkable relations presented by the richest and poorest smaller regions result from chance-distribution is indefinitely more minute even than this inconceivably minute probability.

But since the above lines were written I have gone much further with the illustration of this matter by star-charting. For I have combined in a single chart all the forty large folio charts of Argelander's Atlas, containing no less than 324,198 stars, all presented on the same isographic projection as the accompanying chart. In this map of many stars, the place of the Milky Way is actually 'mapped in' by the stars themselves, not as here, by a separate indication. I would refer those who desire fuller information respecting the arrangements of the stars in space to this chart and its explanation (published by Mr. Brothers, of 14 St. Ann Square, Manchester).

The evidence in favour of special laws of stellar distribution is, however, far from exhausted.[1]

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[1] Indeed, I am unable, within the space here available to me, even to touch on a tenth part of the evidence I have gathered together in my note-books and portfolio of charts.

Quite early in my consideration of the subject I am now upon, the idea suggested itself to me that in the proper motions of the stars we have a means of forming an estimate of the distances of these orbs; and further, of detecting any laws associating them together, whether into streams or clusters; and that the evidence thus obtained was likely to be in many respects more trustworthy than that afforded by the apparent magnitudes of the stars. Two processes of inquiry suggested themselves. The first consisted in a careful comparison of the mean motions of stars of different apparent size, in order to determine whether, on the average, small stars are so far off that we can look upon them as in reality no smaller on the average than those which appear larger. The second consisted in charting down the proper motions, so as to detect any signs of star-drift which might haply appear in different parts of the heavens. I confess that I had not by any means expected results so strikingly confirmatory of my views as those I actually obtained.

The first method of inquiry, instead of giving an average amount of proper motion to the smaller stars somewhat, or perhaps even considerably, greater than was to be expected, according to the theory which sets these stars at an enormous distance, actually gave them a mean motion *equal* to that of stars of the first three magnitudes. It became evident, then, that not only are small stars (I am here speaking of stars visible to the naked eye) mixed up as I had thought with bright stars visible in the same general direction, but

distance is less available to explain the smallness
he stars even than I had supposed. I had thought
certainly a large proportion of the small stars must
reality be very far from us; but it appeared that
proportion of stars whose smallness is so to be
ounted for is in reality exceedingly minute. There
st therefore be myriads of really small stars for
ry leading orb.

The second method of research led to the strange
ilt that in many parts of the heavens a community
motion can be recognised, among star-groups far
ger in extent than any such groups as I had
ected to find thus drifting through space. Know-
that whatever view we form of the sidereal universe,
must yet recognise the fact that in every direction
s at very different distances are visible, I had not
ed to find over any large region of space the
ces of a community of motion. Nor even in small
ions had I hoped to recognise very decided traces of
-drift, because I was conscious that, even with three
four stars really forming a drifting group, there
ld nearly always be found three or four others,
ler much farther off or much nearer, and altogether
ociated from the drifting set. Indeed, I imagined,
en I began the inquiry, that the most remarkable
ance of star-drift in the heavens was that detected
ough differently explained) by Mädler in the con-
lation Taurus.

I found, however, that in other regions a far more nost remarkable instance of all is that illustrated ne accompanying plate. This picture represents notions in the constellations Cancer and Gemini. ill be noticed that though here and there stars rently not belonging to the system appear in same range of view, yet the star-drift is unmisble. The general parallelism of motion is very ing; and the difference in the amount of motion rved in different stars is only what was to be cted in a star-group whose range in distance, if valent to its lateral extent, must be such as fully ccount for the range in the amount of apparent on.

'ig. 6 exhibits one out of many parts of the ens in which different sets of stars are observed to rifting in different ways.

t will be seen that here there are three sets—those ded in the space *a*, those in space *b*, and those left nclosed. These groups are very obviously drifting, in its special direction. The stars within the space β, γ, δ, ε, and ζ of the Greater Bear with three ler stars. Their drift is, I think, most significant. truth the parallelism and equality of motion are to garded as accidental, the coincidence is one of a remarkable character. But such an interpretation no longer be looked upon as admissible. For Mr. gins has found that these stars β, γ δ, ε, and ζ are eceding from the earth at the rate of about seventeen lrifting system. But the peculiarity is only one of series of instances, some of which are scarcely less riking. One of these is presented in fig. 7, in which e proper motions in the stars α, β, and γ Arietis,

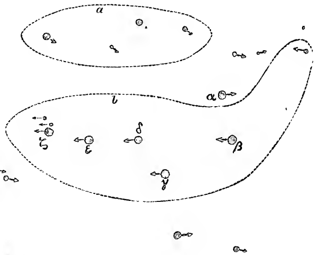

Fig. 6.—Observed Proper Motions of Stars in Ursa Major and Neighbourhood.

d four other stars in the neighbourhood, are hibited.[1]

Here β and γ may be regarded as drifting with α, t having a motion of their own in addition, sufficing account for the want of strict parallelism between their apparent motion and that of *α*. The other stars seem obviously to belong to the same system.

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[1] In all three figures the proper motion indicated by the length the arrow attached to a star corresponds to the star's motion in

I am led by the facts which have here been briefly considered rather to urge those who have time and inclination to inquire carefully into the minuter details of the sidereal heavens than to insist on any views of my own. While I recognise the wisdom and necessity of that course which the Herschels adopted in taking a wide view of the sidereal system, and in dealing rather with general results than with special peculiarities, I think the time has come when another course is possible and advisable. The Herschels having surveyed the field of heaven, it behoves us now to go over it with a close and searching scrutiny. To consider averages *now* is to level the scarcely perceptible undulations in our field of research, as well as its better marked ridges or depressions; whereas we require, on the contrary, to exaggerate the variations of level, so that we may determine with more certainty what are the peculiarities presented by that most interesting field to man's contemplation. Or,

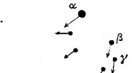

Fig. 7.—Observed Proper Motions of Stars in Head of Aries.

change the illustration, and to quote the words of
e greatest modern master of that kind of research
ich I have been advocating—'We must not be
terred from dwelling consecutively and closely on
ese speculative views by any idea of their hopeless-
ss which the objectors against "paper astronomy"
ay entertain, or by the real slenderness of the material
reads out of which any connected theory of the
iverse has (at present) to be woven. "*Hypotheses*
ngo"[1] in this stage of our knowledge is quite as
od a motto as Newton's "*Non fingo*"—provided
ways they be not hypotheses as to modes of physical
tion for which experience gives no warrant.'[2]

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[1] It should be noticed that Newton defined what he meant by
potheses' when he said '*hypotheses non fingo*,' and that he did
, object to what have now commonly (through the careless use of
rds) come to be regarded as hypotheses. Newton defined a hypo-
sis as whatever is not deduced from the phenomena.

[2] From a letter addressed by Sir J. Herschel to the present
iter, August 1, 1869.

CHAPTER XII.

HE NEBULÆ: ARE THEY EXTERNAL GALAXIES?

e last chapter I have indicated reasons for be-
g that the sidereal system extends far beyond
inge of the most powerful telescopes man has
een able to construct. It need hardly be said
supposing this view to be correct, we cannot
ly see any external galaxies unless they surpass
wn many thousands of times in richness and
our. Every analogy that we have for our
ice points to the conclusion that if our galaxy
imits, and there exist in space other galaxies, then
outer systems must be separated from ours by
exceeding the dimensions of the several galaxies
thousand or many million-fold in extent. We
that the distances separating the satellites from
primaries exceed in an enormous ratio the dimen-
of the satellites. The distances separating the
s from each other exceed in an enormous ratio
mensions of the planets. The distances sepa-
our solar system from others enormously exceed
imensions of the various solar systems. And

parating our sidereal system from other similar
stems in space must exceed in an enormous ratio
e dimensions of our galaxy, and of all other such
stems.

That the sidereal system has limits I do not doubt.
course it *may* be co-extensive with space—that is,
solutely infinite in extent. But we have no reason
r believing that in rising step by step, from system
system, until we have reached the highest class of
stem known to us, we have reached the real summit
that perhaps altogether limitless range of steps.
e know, indeed, that if light do not suffer extinction
traversing space (and we have as yet no evidence
at it does), the extent of the sidereal system *must* be
nited, since otherwise the whole of the star-lit sky
ould shine with the brilliancy of sun-light.[1] And we

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[1] This is, perhaps, obvious; but if not, the following proof may
accepted:—Let the whole of space be conceived divided into
herical shells, having our earth at the centre, the thickness of
ch shell being τ. Then taking two shells, one at a distance r,
e other at a distance r' (both r and r' much greater than τ), we
that the number of stars in these shells will be proportional to
and $r'^2\tau$ respectively—that is, will vary as the product of the
ckness of the shell and the square of its radius. (Here I am not
ncerned with those departures from uniformity which I have
nsidered in the last chapter, because I suppose each shell large
ough to include within it all varieties of distribution and ag-
gation. This applies also to what follows.) Now the average
parent size of the stars of one shell will be to the average ap-
ent size of stars in the other in the inverse proportion of the
pective radii of the shells, the intrinsic brightness of the light
eived from the stars of each set being equal. Thus the total
ount of light from the stars of one shell is to the total amount of

may carry this argument even farther. For, though the sidereal system should be limited, but other systems similar to it spread throughout the infinity of space, there would still result this ineffable blaze of light, surpassing the light of day as greatly as the vault of heaven surpasses the disc of the sun. And this again would be true, though this system of systems were limited in extent, but surrounded by similar systems of systems in the infinity of space. And so on, let the order of systems which finally becomes infinite in number be what it may. There is only one way to escape from this limitless series of system-orders—that is, by accepting as true the hypothesis that light suffers extinction as it voyages through space. But it is worth noticing, when we are actually dealing with the infinity of space, and when, therefore, limitless conceptions are not paradoxical, but in reality as available for our purposes as finite conceptions would be, that if we

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supposing the amount of light received from one shell to be $\frac{1}{k}$th part of that which would be received if the whole celestial sphere were as bright as the sun's (that is, as a star's) disc—k being enormously large, the amount received from the other is also $\frac{1}{k}$th of this amount, and the total from all the shells must therefore be

$$\frac{1}{k}+\frac{1}{k}+\frac{1}{k}+\frac{1}{k} \quad . \; . \text{ to infinity.}$$

Now, by taking k terms of this series (or k shells out of our infinite series of shells) we should get unity, that is, the whole heavens lighted up with star-light or sun-light. There would be a proportion of stars in the same visual line, and so hiding each other; but since we can take 2 k, 3 k, or *infinity* times k if need be, there can be no doubt that the whole heavens would be lighted up with solar brightness. Compare next note.

adopt the belief in an infinite succession of orders
systems; that is, first satellite-systems, then plane-
y-systems, then star-systems, then systems of star-
tems, then systems of systems of star-systems, and
on to infinity; and if we accept as true of this in-
ite series what we know to be true of the part within
ken, viz. that the distance between the components
ming any system is indefinitely great compared with
dimensions of these components, we no longer have
a conclusion that the whole heavens would be
hted up with stellar (that is, with solar) splendour;
en though, in this view of the subject, there are in
lity an infinite number of stars, just as in the view
ording to which the sidereal system extends without
erruption to infinity.[1]

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[1] It is clear that we no longer get, as in the previous note, a
es of equal small terms. If we take our infinite series of shells
before we get for the sidereal system n times $\frac{1}{k}$ where n is finite,
therefore $\frac{n}{k}$ finite. We must indeed assume $\frac{n}{k}$ to be small, and
of other similar ratios presently to be dealt with. With respect
the system of systems, we have these considerations to guide
—Any of the spherical shells within this system must supply to
skies an amount of light indefinitely less than one of the shells
hin the sidereal system itself, say, $\frac{1}{k'}$th part only, k' indefinitely
e. But the number of shells falling within that system is very
ch greater, say, n' times as great where n' is finite. Therefore
get for the total amount of light coming from the system of
ems a quantity proportional to $\frac{n\,n'}{k\,k'}$. And so for the system of
em of systems we get a quantity proportional to $\frac{n\,n'\,n''}{k\,k'\,k''}$,
ere k'' is indefinitely large, n'' very large. And for each succes-

But whether we adopt this or any other view of the way in which external systems are arranged, this at large, and a very large indeed. Suppose $\frac{\nu}{\kappa}$ to be the largest of all these multipliers, then the total amount of light received from the infinite system of systems is proportional to less than

$$\frac{n}{k}\left(1+\frac{\nu}{\kappa}+\frac{\nu^2}{\kappa^2}+\frac{\nu^3}{\kappa^3}\ldots\text{ to infinity}\right),$$

(in which ν is supposed to be less than κ), *i.e.* to less than $\frac{n}{k}\left(\frac{\kappa}{\kappa-\nu}\right)$, a finite quantity—which will even be minute if k and κ are severally much greater than n and ν.

This particular mode of escaping from the difficulty suggested by the illumination of the heavens, without adopting the theory that light suffers extinction in its passage through space, occurred to me while I was preparing a series of papers entitled A New Theory of the Universe, which appeared in the 'Student' in the spring of 1869; and I there exhibit the considerations just dealt with. I was much pleased to find from a letter of Sir John Herschel's that the same idea had (probably earlier) suggested itself to him; and I was thus encouraged to believe that I had not gone very far astray in the whole series of papers, which of the matter in question had seemed to me the most speculative portion. The following are the words in which Sir John Herschel expresses the ideas above dealt with :—'One of the arguments advanced in favour of the spatial extinction of light was that, if there is not such extinction, the whole heavens ought to be one blaze of solar light—admitting the universe to be infinite—because it was contended that there could then be no direction in space in which the visual ray would not encounter a star (*i.e.* a sun). This argument is fallacious, for it is easy to imagine a constitution of a universe literally infinite which would allow of any amount of such directions of penetration as *not* to encounter a star. Granting that it consists of systems subdivided according to the law that every higher order of bodies in it should be immensely more distant from the centre than those of the next inferior order—this would happen. Thus in our own, the moon is very near the earth, the satellites to their primaries. These primaries are immensely more distant from the sun, *their* centre; the fixed stars again still *more* immensely more remote from the sun. Suppose *our* system to terminate with the visible fixed stars; then imagine a system of such systems as remote from each other, *in comparison with their own dimensions*, as the distance y rate is certain, that if the stars at the outer parts our own sidereal system be beyond the ken of our ost powerful instruments—and I have shown that ere are strong reasons for this conclusion—then the nponent suns of external galaxies cannot by any ssibility be visible. So that, according to this view, resolvable nebulæ, at least, must be dismissed from e category of external galaxies. Nor will it be ought probable that irresolvable nebulæ are external laxies, if once that view of the extent of the sidereal stem is adopted.

But there are independent considerations on which refer now to dwell, for believing that all the nebulæ long to the sidereal system.

It will hardly be necessary, let me remark in passg, for me to point out how this matter is associated th the subject of other worlds. It is true that when ce it is admitted that there are external galaxies, it y be looked on as a matter of small importance (so as the subject of this treatise is concerned) whether can actually see those galaxies or not. I am not, instance, in the same position as Dr. Whewell, who igned to the nebulæ what I take to be their true ce in the universe, with the express object of erthrowing the belief that there exist other galaxies vast as the sidereal, or vaster, thronged with suns ich are severally the centres of planetary systems, thin which again are worlds as well suited to be the

the fixed stars in comparison with the planetary system; such of life as this earth on which we dwell. But, h my purpose is different from his, it is equally ary that I should insist on the true position of bulæ. Because, if these objects form indeed parts e sidereal system, the relations they present are reme importance. They exhibit to us within the ls of our galaxy systems altogether different from lar system, and thus suggest ideas of other classes rlds peopled with their own peculiar forms of life, tinct perchance even in their general character- from any found amid the systems circling round as the forms of life in Venus or in Mars must their special characteristics from those existing r own earth.

reed from those analogies which led the elder hel to regard the stellar nebulæ—resolvable and lvable[1]—as external star-systems, let us consider relations presented by these and other nebulæ ut reference to preconceived opinions.

e must first pay attention to one of the most ng of the discoveries which the spectroscope has nabled man to make—the discovery that certain æ are gaseous. It is necessary to consider this ficant discovery, rather than those which were rst to exhibit the real place of the nebulæ in our ne, because we shall thus be able to divide the æ at once into two great classes, instead of being

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y irresolvable stellar nebulæ I mean those nebulæ which,

d to this arrangement by following out the history
those long processes of research by which the two
eat orders of nebulæ were long since separated from
ch other under the piercing scrutiny of Sir William
erschel.

The reader will see how the spectroscope could at
ce resolve a question which ordinary observations
uld be all but powerless to deal with. The nebulæ
ing self-luminous, the nature of the matter which is
e source of their light would be shown by the cha-
cter of the spectrum, as distinctly as though that
atter were actually present in the laboratory of the
ectroscopist.

Mr. Huggins thus describes the observation which
st revealed the true nature of certain orders of the
bulæ. The object under examination was a nebula
Draco, belonging to the class of planetary nebulæ.
On August 19, 1864, I directed the telescope armed
th the spectrum apparatus to this nebula. At first
suspected some derangement of the instrument had
ken place, for no spectrum was seen, but only a short
ne of light perpendicular to the direction of dispersion
hat is, to what would in the case of solar light be
e *length* of the spectrum). I then found that the
ght of this nebula, unlike any other extra-terrestrial
ght which had yet been subjected by me to prismatic
alysis, was not composed of light of different re-
angibilities, and therefore could not form a spectrum.
great part of the light from this nebula is mono-

mains concentrated in a bright line, occupying the position of that part of the spectrum to which its light corresponds in refrangibility. A more careful examination, however, showed that—a little more refrangible than the bright line, and separated from it by a dark interval—a narrower and much fainter line occurs. Beyond this, again, at about three times the distance of the second line, a third exceedingly faint line was seen. The positions of these lines in the spectrum were determined by a simultaneous comparison of them in the instrument, with the spectrum of the induction spark taken between electrodes of magnesium. The strongest line coincides in position with the brightest of the air-lines. This line is due to nitrogen.' . . . 'The faintest of the lines of the nebula agrees in position with a line of hydrogen.' The other bright line was not found to correspond with a known line of any terrestrial element. Besides the bright lines, an exceedingly faint spectrum was just perceived for a short distance on both sides of the group of bright lines. Mr. Huggins suspected that this was not uniform, but crossed by dark spaces. Subsequent observations on other nebulæ[1] induced him 'to regard this faint ectrum as due to the solid or liquid matter of the icleus, and as quite distinct from the bright lines to which nearly the whole of the bright light from ie nebula is concentrated.'

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[1] One of the most interesting of Mr. Huggins's researches into the subject of the light of nebulæ is his attempt to determine its intrinsic brilliancy. By comparing the light of certain gaseous nebulæ with that of a sperm candle (of the size called 'six to the pound'), he found that these objects, assumed to be continuous, shine with a light varying in intrinsic brilliancy from the 1,500th to the 20,000th of that of such a candle. By a strange misconception, Mr. Lockyer, in discussing Mr. Huggins's result, speaks of the comparison as though it related to the absolute brightness of the

Thus was solved a problem which had, for the best irt of a century, perplexed astronomers. There was ot, indeed, a full answer to all the questions of in- rest associated with the problem. But it had been id down by Sir William Herschel, as a legitimate nclusion from observation, that certain orders of the ebulæ are gaseous, and astronomers had ranged them- lves for and against this proposition. Telescopic aprovements had seemed at length to turn the scale favour of those who held Sir William Herschel to ive been mistaken. Already the problem had seemed l but definitely settled. And then in a moment this oservation by Mr. Huggins had reversed the whole atter. It was now established beyond all possibility future question that on the main point the greatest modern astronomers had been altogether in the ght.

The orders of nebulæ which give a spectrum of right lines would seem from Mr. Huggins's observa- ons to be (i.) the planetary nebulæ, (ii.) the ring ebulæ, (iii.) the irregular nebulæ. The spiral nebulæ

ebulæ, saying that 'such a candle a quarter of a mile off is 20,000 mes more brilliant than the nebula.' Mr. Huggins's result is holly distinct from this, and much more important. His com- arison relates to the intrinsic luminosity of the nebular substance. ot to the *quantity* of light received from the nebulæ. (The dis-

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for the most part, to give a continuous spectrum, me of these objects give the bright line spectrum tive of gaseity. The orders of nebulæ which a continuous spectrum appear to be the follow- –(i.) star groups, (ii.) clusters, regular and irre- , and (iii.) easily resolvable nebulæ. Of the lvable nebulæ a large proportion seem to be us.[1]

ere, then, we find the nebulæ ranged into two tant divisions, apparently separated by a distinct f demarcation. Yet one is tempted to inquire er these divisions may not in reality run into other by the fact that among nebulæ of certain are objects belonging to both divisions. And act that beneath the bright-line spectrum of the us nebulæ a faint continuous spectrum may be seems also to point in the same direction. We that, so far as the telescopic appearance of the læ is concerned, there is very striking evidence

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[1] The following classification of nebulæ in this respect, by Lord ntown, is interesting as indicating the results of observations with so powerful an instrument as the great Parsonstown ope (the 6-feet reflector).

	Continuous Spectrum.	Gaseous Spectrum.
Clusters	10	0
Certainly or probably resolved .	5	0
Certainly or probably resolvable .	10	6
Blue, or green, no resolvability .	0	4
No resolvability detected .	6	5
	—	—
Total observed . . .	31	15

a gradual progression from clusters to irresolvable ulæ; and therefore we are led to inquire whether spectroscope conveys a similar lesson.

Now this question could only be answered satisfacily by the observation of a series of nebulæ having ctra progressively varying, from bright lines on an ost invisible continuous spectrum to a continuous ctrum with the same bright lines superposed on it, almost imperceptible, because their brightness so le exceeded that of the continuous spectrum. We ve no evidence of such completeness. But Captain rschel has observed in the southern heavens a clusing nebula with a continuous spectrum, on which could just detect the three bright lines seen in the ctra of the gaseous nebulæ. So far as this evice extends, the conclusion is obvious that the ious orders of nebulæ are orders of but a single ily. It will be seen presently that this conclusion, ich is strikingly corroborated by other evidence, a very important bearing on the views we are to m respecting the relations between the nebulæ and sidereal system.

The first process by which we must attempt to m a correct estimate of the nebular system corrends to Sir William Herschel's process of starging. We must inquire according to what general s the nebulæ are spread over the vault of heaven.

Now, when this is done, it appears that there is well marked peculiarity in the arrangement of the

the galactic circle itself. *The nebulæ seem to withdraw themselves from the neighbourhood of the galaxy.* In the northern heavens they cluster very definitely towards the pole of the galaxy; in the southern they are arranged in streams and clustering aggregations, but the galaxy itself is, in either case, left almost clear of nebulæ.

If this peculiarity is accidental, the coincidence involved is most remarkable. Had there been a zone of nebulæ, and that zone had shown a tendency to coincidence with the Milky Way, the relation would have been thought strikingly indicative of a real association between the nebular and the sidereal systems. But is the direct converse of this relation more likely to be the effect of chance? Have not observers and experimenters concluded (in every other similar instance) that a law of contrast is as indicative of a real connection as a law of association? Is it not most surprising, therefore, that nearly all astronomers who have considered the relation in question have regarded it as affording strong evidence that the nebular system is wholly dissociated from the sidereal?

Next let us turn to special features. In the first place, let us inquire whether the different orders of nebulæ exhibit any peculiarities of arrangement.

We find that clusters exhibit a very marked preference for the neighbourhood of the Milky Way; resolvable nebulæ seem to prefer the galactic zone, but not in so decided a manner; and it is only among the irresolvable nebulæ that we recognise that withdrawal from e Milky Way which had seemed characteristic of the ole nebular system before we considered its several lers. The fact that the irresolvable nebulæ form out four-fifths of the total number will account for e circumstance that a peculiarity really appertaining that order alone should appear to belong to the ole system of nebulæ.

Again, the planetary and irregular nebulæ are found affect the neighbourhood of the Milky Way. I have eady mentioned that these objects are gaseous.

It is easy to see what general conclusions may be duced from the peculiarities here touched upon. viously the first shows us most distinctly that there a relation between propinquity to the Milky Way d the character of nebulæ as respects resolvability— elation which points in the most decisive manner to e existence of a close association between the sidereal stem of which the Milky Way certainly forms part, d the nebular system from which clusters and re- lvable nebulæ cannot reasonably be separated. It is ually obvious that the second peculiarity indicates e existence of a close association between the Milky ay and the character of the nebulæ as respects seity; a relation which brings all the gaseous nebulæ to close association with the sidereal system, since we ow that among the extra-galactic nebulæ there are any which are principally formed of the very same ses which appear in the irregular and planetary bulæ. When we consider that those peculiarities seemed to indicate that the various orders of nebulæ merge into each other by indefinable gradations are both associated in a very distinct manner with the most marked peculiarity of the sidereal system, and when to this we add what has been already suggested by the relation of contrast between the irresolvable nebulæ and the Milky Way, the conclusion seems forcibly impressed upon us that the nebular and the sidereal systems are but different parts of one single scheme.

But I pass on to other evidence, independent of what has hitherto been adduced, and pointing with equal force to the same conclusion.

In the northern heavens it is not very easy to exhibit any general law of arrangement associating the nebulæ and the fixed stars. For reasons which yet remain to be detected, there are in fact many marked points of difference between the whole character of the heavens on the northern and on the southern side of the galactic zone. But even in the northern heavens one peculiarity has been remarked, which is well worthy of careful consideration. Sir William Herschel, while prosecuting his series of researches among stars and nebulæ, was struck by the circumstance that, after sweeping over a part of the heavens which was unusually barren, he commonly met with nebulæ; insomuch that it was his practice at such times to call to his assistant (his sister, Miss Caroline Herschel) to 'prepare for nebulæ.' This peculiarity was noticed also by Sir John Herschel.

Now what are we to understand by such a relation

this? Can we suppose that, owing to some strange
cident, external galaxies have been placed always
posite the barest regions of the sidereal system? Or,
tting aside such a notion as obviously incredible, are
e to imagine that when searching over those barren
gions the astronomer has a better chance of detecting
bulæ than where stars are more richly strewn, be-
use the sky is less filled with glare? We are forced
dismiss this notion that the barren regions of the
avens are thus in a manner the spy-holes of the
lereal system, by the fact (presently, and for another
rpose, to be dwelt on more at length) that in the
gellanic Clouds, where stars of all magnitudes are
hly strewn, nebulæ, even down to the very faintest
lers, are more abundant than in any other region of
e heavens. We have then no other conclusion to
m, but that the association thus observed between
arless regions and richness of nebular distribution
licates a very close relation indeed between stars and
bulæ; that, in fact, *the nebulæ in a sense represent*
e missing stars; that the region where those nebulæ
ppear has been drained of star materials, so to speak,
order to form them.

In the southern heavens yet clearer proofs exist of
association between the stellar and nebular systems.
e do not recognise in the northern skies any well-
arked star-streams. In the southern skies, however,
ch streams have been recognised from the earliest
es. The constellations Hydra and Eridanus, the

band between the Two Fishes,[1] indicate how clearly the ancients traced certain well-marked star-streams. The moderns have traced the extension of some of these streams in the constellations Grus, Hydra, Reticulum, &c. into the near-neighbourhood of the southern pole. Now the nebulæ in the southern heavens exhibit a well-marked tendency to aggregate into streams. So that, in this mere resemblance between the general characteristics of the stellar and nebular systems in the southern heavens, we have a somewhat remarkable evidence of association. But when we consider the disposition of the two sets of streams—the stellar and the nebular—this evidence is very much strengthened. There is found to be a well-marked correspondence between the nebular and stellar streams, not merely as respects general position, but even in minute details—the nebular streams following the windings of the stellar ones. Such a relation would be very remarkable, even were it observed but in a single instance. Since, however, all the well-marked star-streams in the southern heavens are associated with well-marked nebular streams, no doubt can remain that the relation is not a mere coincidence, but indicates a real association between the nebular and stellar systems.

But yet more striking evidence remains to be considered.

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[1] Though Pisces is not a southern constellation, yet it is south of the galactic circle, to which I am for the moment referring the constellations

In the southern heavens there are two strange uds of milky light, which have long been known by ors as the Magellanic Clouds, but are commonly led by astronomers the Nubeculæ. Each of these ects, when examined with the telescope, is found be constituted, like the Milky Way, of multitudes small stars. But unlike the Milky Way, the beculæ contain within their bounds many nebulæ all orders. In fact, each of the Nubeculæ is at ce a star-cluster and a cluster of nebulæ.

Now there can be no doubt whatever that the ociation here is not accidental, that we do not by ne strange chance see a great star-cluster in the ne direction as a much more distant and much ter cluster of external galaxies. Nor again can re be any doubt that the generally circular figure each Nubecula indicates a general approach to the nerical form in the case of each cluster. The pro- bility that by some strange accident a cluster of indrical shape[1] might be so placed as to exhibit to a circular figure is exceedingly small; but the nce that two such clusters should be presented in exceptional a manner may be regarded as evanes- nt. We are compelled, then, to believe that, within limits of spheres so placed as to subtend a small gle to the eye, stars of all magnitudes between the venth and the twelfth inclusive are mixed up with bulæ of all degrees of resolvability. 'Taking the apparent semi-diameter of the Nubecula Major at three degrees,' says Sir John Herschel, 'and regarding its solid form as, roughly speaking, spherical, its nearest and most remote parts differ in their distance from us by a little more than a tenth part of our distance from its centre.' 'It must therefore be taken as a demonstrated fact,' he adds presently, 'that stars of the seventh and eighth magnitude and irresolvable nebulæ may co-exist within limits of distance not differing in proportion more than as nine to ten.' This demonstrated fact of Sir John Herschel's is the very fact to which I had been led by other considerations, the fact, namely, that the nebulæ are not external galaxies, but intimately associated with the sidereal system, of which, in fact, they form part and parcel. Dr. Whewell, accepting Sir John Herschel's reasoning as conclusive on the point, adopted the same view. And although Sir John Herschel himself, immediately after establishing this noteworthy conclusion, speaks respecting it in a tone of philosophic caution, it must not be forgotten that to his clear vision the association between nebulæ and fixed stars had presented itself as a demonstrated fact, and that even in the latest editions of his noble work on astronomy he has not altered the words in which he has spoken of that association.

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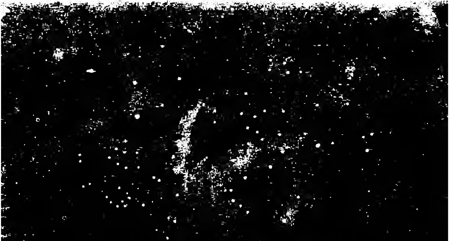
[1] Or, more correctly, a cluster shaped like a long frustum of a

Lastly, and perhaps most strikingly, the association between stars and nebulæ is indicated by the obvious connection between the figure of the irregular nebulæ and the arrangement of the star-groups seen in the same field of view. There is not one of the

egular nebulæ which does not exhibit this peculiarity
the most striking manner. This may be asserted
n of those nebulæ with respect to which Sir John
rschel has remarked that the arrangement may be
idental. His own pictures seem to me to prove in
most convincing manner that no such explanation
be accepted. The mere aggregation of a large
mber of stars in the very heart of a nebula might
an accident. The fact, for instance, that the great
egular nebula surrounding the star Eta Argûs
rees exactly in position with the greatest condensa-
n of the wonderfully rich portion of the Milky Way
which that surprising variable lies, might be a
re coincidence, though in any case it would be a
ange one. But when one examines the structure
this and similar nebulæ, and finds that the stars are
anged in a manner most obviously related to the
angement of the nebular condensations (or folds as
may almost say), one cannot doubt that a real and
imate bond of association exists between the stars
d the nebulous masses around them. If the exten-
n of the milky light of the great Orion nebula to
star ι in the sword, which is centrally involved in
ong nebulosity; to ε in the belt, which is similarly
volved; and to several other stars in the constellation
l alike in occupying regions of increased nebular con-
nsation), be a mere accidental coincidence, then the
vs of probability had better be forgotten as soon as
ssible: for, as at present understood, they can only



The Nebula Messier 17, as seen with Lassell's 4 feet Reflector.

[illegible] & Co.

the accompanying Plate is given a picture of the Messier 17, as observed with Lassell's four-feet r at Malta. I have selected it as affording a riking instance of the particular form of associa- have just been dealing with. No one can, I refuse to recognise the fact that the system of hown in this drawing is not accidentally seen ed on a distant galaxy, but forms part and parcel nebula itself.[1]

e nebula around the strange variable star, Eta already referred to, is another remarkable e of this sort. More than two years ago I ed to make two predictions about this object. rst was a tolerably safe one. I expressed my that the nebula would be found to be gaseous. Mr. Huggins's discovery that the great Orion is gaseous, it was not difficult to see that the nebula must also be so. At any rate, this has established by Captain Herschel's spectroscopic re- es. The other prediction was more venturesome. hn Herschel, whose opinions on such points one always prefer to share, had expressed his belief he nebula lies far out in space beyond the stars n the same field of view. I ventured to express inion that those stars are involved in the nebula. there came news from Australia that Mr. Le

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r John Herschel, referring to the accompanying Plate, ex- the opinion that the apparent association need not neces- e real. The discovery of nebular tracts in the Pleiades has ur, with the great reflector erected at Melbourne, found that the nebula has changed largely in shape e Sir John Herschel observed it. Mr. Le Sueur ordingly expressed his belief that the nebula lies *rer* to us than the fixed stars seen in the same field iew. More lately, however, he has found that the Eta Argûs is shining with the light of glowing rogen, and he expresses his belief that the star has sumed the nebulous matter near it. Without eeing with this view,[1] I recognise in it a proof that Le Sueur now considers the nebula to be really ciated with the stars around it.

Amongst other instances may be cited the nebula nd the stars c^1 and c^2 in Orion. In this object remarkable nebulous nodules centrally surround double stars. Admitting the association here to real (and no other explanation can reasonably be nitted), we are led to interesting conclusions respect- the whole of that wonderful nebulous region which rounds the sword of Orion. We become certain t the other nebulæ in that region are really asso- ed with the fixed stars there; that it is not a mere ncidence, for instance, that the middle star in the of Orion is involved in nebula, or that the lowest of the sword is similarly circumstanced. It is a timate inference from the evidence that all the

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[1] My belief is that as the star recovers its brilliancy observation show that the nebula in its immediate neighbourhood becomes hter (*not* fainter through being consumed as fuel). In fact, I disposed to regard the variations of the nebula as systematic,

e in this region belong to one great nebulous
which extends its branches to these stars. As a
y hand this nebulous region seems to gather the
ere into close association, showing us, in a way
is no misinterpreting, that these stars and the
form one system.

will be noticed, as respects the two proofs on
I have last dwelt, that they seem directly
ed to those which I first quoted. One cannot
it might be urged, that the nebulæ are asso-
with the sidereal system because they are least
ous where there are most stars, and *vice versâ*;
at the same time one draws the same conclusion
he aggregation of the nebulæ in streams or
s where there are streams and clusters of stars,
n the fact that stars are seen actually mixed up
ebulous matter. At first sight this objection
just; but, on consideration, it will be found that
ity, the two seemingly contrary lines of argument
n the same direction. When we find the nebulæ
ed where stars are wanting, and *vice versâ*,
nclude that there is some reason for this pecu-
, and that that reason must involve some sort of
tion between the nebulæ and the stars; we see,
r, that the relation is accounted for if we suppose
n these cases, either the formation of nebulæ
ined a region of material from which single stars
otherwise have been formed, or *vice versâ*. Why,

ecked, we cannot say; nor can we account for the ntrary peculiarity in another region: but we feel rtain that some cause must exist for both relations, cause the results are too marked to be due to cident. Now, in the case where we find both rs and nebulæ abundant in particular parts of the avens, we feel equally certain that the result is not cidental. Even though there were not here, as in e former case, the evidence of a clearing of star-aterial from certain regions, we could not doubt that e association of stars and nebulæ was real, and not parent. But in reality there is *here*, precisely as in e former case, a gathering together of stellar matter to certain regions. The very existence of such a ream as Eridanus or Hydra, and of such a cluster as e greater or lesser Magellanic Cloud, implies the tion of such a process of segregation. A stream would t be recognisable if it were not bounded by relavely bare regions. Clusters like the Nubeculæ *might* visible even on a rich sky—and were the sidereal avens richly strewn with stars round these objects I ould be disposed to admit that there was a difficulty my theory. But what is the fact? Not only is each the Nubeculæ placed in a region obviously bare lucid stars, but Sir John Herschel, speaking of e telescopic aspect of the neighbourhood of these ysterious clusters, dwells again and again on its verty. 'A miserably poor and barren region,' he ys of one field near the Nubeculæ. 'The access to the

sert.' What evidence could more clearly point
e fact that these great clusters are gathered out
a vast region of space? Their internal structure
nes us how such a process of segregation leads to
birth of nebulæ as well as stars. The whole
ry of the sidereal system is indeed taught us in
Magellanic Clouds and the great streams of inter-
d stars and nebulæ which flow towards them as
s towards some mighty lake.

t remains that I should sum up the results
h I have discussed in the last two chapters. It
seemed to many that my views tend largely to
nish our estimate of the extent of the sidereal
m. The exact reverse is the case. According
ccepted views there lie within the range of our
powerful telescopes millions of millions of suns.
rding to mine the primary suns within the range
r telescopes must be counted by tens of thousands,
y hundreds of thousands at the outside. What
this diminution of numbers imply but that the
e separating sun from sun is enormously greater
accepted theories would permit? And this in-
e implies an enormous increase in the estimate we
o form of the vital energies of individual suns.
he vitality of a sun, if one may be permitted the
ession, is measured not merely by the amount of
er over which it exercises control, but by the ex-
of space within which that matter is distributed.
an orb a thousand times vaster than our sun, and

housand-fold the combined mass of all the planets of
e solar system: so far as living force is concerned,
e result is *nil*. But distribute that matter through-
t a vast space all round the orb: that orb becomes
once fit to be the centre of a host of dependent
rlds. Again, according to accepted theories, when
e astronomer has succeeded in resolving the milky
ht of a portion of the galaxy into star, he has in
at direction, at any rate, reached the limits of the
ereal system. According to my views, what he has
lly done has been but to analyse a definite aggrega-
n of stars, a mere corner of that great system. Yet
ce more, according to accepted views, thousands and
ousands of galaxies, external to the sidereal system,
n be seen with powerful telescopes. If I am right,
e external star-systems lie far beyond the reach of
e most powerful telescope man has yet been able to
nstruct, insomuch that perchance the nearest of the
tlying galaxies may lie a million times beyond the
nge even of the mighty mirror of the great Rosse
escope.

But this is little. Wonderful as is the extent of
e sidereal system as thus viewed, even more won-
rful is its infinite variety. We know how largely
odern discoveries have increased our estimate of the
nplexity of the planetary system. Where the ancients
cognised but a few planets, we now see, besides the
nets, the families of satellites; we see the rings of
turn, in which minute satellites must be as the sands

eroids; myriads on myriads of comets; millions illions of meteor systems, gathering more and richly around the sun, until in its neighbourhood form the crown of glory which bursts into view he is totally eclipsed. But wonderful as is the y seen within the planetary system, the variety n the sidereal system is infinitely more amazing. es the single suns, there are groups and systems reams of primary suns; there are whole galaxies nor orbs; there are clustering stellar aggregations, ng every variety of richness, of figure, and of oution; there are all the various forms of nebulæ, able and irresolvable, circular, elliptical, and ; and lastly, there are irregular masses of luminous clinging in fantastic convolutions around stars ar-systems. Nor is it unsafe to assert that other and varieties of structure will yet be discovered. t hundreds more exist which we may never hope ognise.

ut lastly, even more wonderful than the infinite y of the sidereal system is its amazing vitality. d of millions of inert masses, we see the whole ns instinct with energy—astir with busy life. reat masses of luminous vapour, though occupy- ountless millions of cubic miles of space, are d by unknown forces like clouds before the er breeze; star-mist is condensing into clusters; usters are forming into suns; streams and clusters rsuing their stately path through space, rejoicing as ants to run their course extending on all sides the ighty arm of their attraction, gathering from ever w regions of space supplies of motive energy, to transformed into the various forms of force—light d heat, and electricity—and distributed in lavish undance to the worlds which circle round them.

Truly may I say, in conclusion, that, whether we gard its vast extent or its infinite variety, or the nazing vitality which pervades its every portion, the dereal system is, of all the subjects man can study, e most imposing and the most stupendous. It is as book full of mighty problems—of problems which are yet almost untouched by man, of problems which it ight seem hopeless for him to attempt to solve. But ose problems are given to him for solution; and he *ill* solve them whenever he dares attempt to decipher ight the records of that wondrous volume.

CHAPTER XIII.

SUPERVISION AND CONTROL.

a peculiarity of the subject of other worlds than
that it suggests more strikingly than any other
in difficulties in connection with conceptions as to
rvision and control exercised over the universe.

Let us consider definitely (even though we must
nable to conceive clearly or at all) the infinities
ave to deal with.

Ve know that space must be infinite. If the region
which stars and nebulæ are scattered in incon-
ble profusion be limited, if beyond lies on all sides
st void, or if, instead, there be material bounds
sing the universe of worlds on every hand, yet
e are the limits of void or bound? Infinity of
e, occupied or unoccupied, there must undoubtedly
Of this infinity it has been finely said that its
re is everywhere, its boundary nowhere. Now,
her within this infinity of space there be an in-
of matter is a question which we cannot so cer-
y answer. Only, if we were to accept this as

ich at least seems reasonable and probable—then it uld follow that matter as well as space must be inite, since any finite proportion of infinity must elf also be infinite.

Time also must undoubtedly be infinite. If the tion of time which has hitherto been, or which will reafter be, occupied with the occurrence of events whatever sort) were preceded and will be followed a vast void interval, yet there can be neither be-nning nor end to either of those bounding voids. finity of time, occupied or unoccupied, there must doubtedly be. And though it is not possible for us know certainly that there has been no beginning, or at there will be no end to that portion of time which occupied with the occurrence of events (of whatever t), yet it appears so unreasonable to conceive that occupied time bears an infinitely great proportion to cupied time that we seem led to the conclusion that cupied time is infinite—or, more definitely, that re has been no beginning and will be no end to sequence of events throughout the infinitely ex-nded universe.

Now to conceive of limits to the wisdom and power One whose realm is infinite in extent and in dura-n is obviously to conclude that the ruler is in-itely incompetent to rule over His kingdom: for re can be no relation between the finite and the inite save the relation of infinite disproportion.

Senses such as we have we can no more attribute feet. Nor can we conceive in what way He can be cognisant of material processes which we only recognise through their material effects. Yet we can scarcely conceive of Him as other than cognisant of all those processes by which our senses can be affected.

But before considering the nature of such a Being's supervision of His universe, we may proceed a step further. The senses we possess are sufficient to indicate to us the possible existence of senses not merely far more acute, but of a wholly different kind. By the sense of touch, for instance, we can indeed recognise the feeling of heat; but it is easy to conceive of a sense (analogous to that by which light is made to teach us of the aspect of external objects) enabling men to judge of the figure, substance, internal structure, and other qualities of an object by the action of the heat-waves proceeding from it. Or again, electricity, instead either of light or of heat, might be the means of communicating intelligence as to the qualities of objects. We can conceive also of a sense bearing the same analogy to sight that the spectroscope bears to the telescope. And a hundred kinds of sense, or in other words, a hundred modes of receiving intelligence about what exists or is going on around us, might be readily conceived.

Yet once more, we know that reason is able to range beyond the action of the senses. Man is able to assure himself that events have happened which yet have produced no direct effect upon any of his senses. By the exercise of reason he becomes as well assured of h events as though they had actually passed before eyes. An analogous power, but infinite in degree, nitely rapid in its operation, and infinite in the ent of space and time over which it ranges, we may ceive to be possessed by a true Ruler over the verse.

And now let us notice some of the conclusions to ich these considerations tend.

Let us first deal with the teachings of that sense ich is the most far-reaching[1] of all the faculties en to man—the sense of sight.

In a little treatise called 'The Stars and the Earth,' blished anonymously several years since, some re- ts of modern discoveries respecting light were dealt h in a very interesting manner. I propose to follow path of thought indicated in that treatise, as a ing introduction to wider conceptions of supervision l control over the universe.

We know from Römer's researches, and even more ely from the phenomenon termed the aberration of fixed stars, that light does not travel with infinite ocity. Its speed is indeed so enormous that, com- ed with every form of motion with which we are niliar, the velocity of light appears infinitely great. a single second light traverses a space equal to eight times the circumference of the earth; and therefore in travelling from any visible object on the earth to the eye of a terrestrial observer, light occupies a space of time indefinitely short. Yet even as regards such objects as these light has occupied a real interval of time, however minute, in reaching the eye; insomuch that we see objects not as they are at the moment we perceive them, but as they were the minutest fraction of a second before.

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[1] Most persons, if asked which sense comes next to sight in respect, would answer hearing. Yet *touch*—or rather *feeling*— a range far exceeding that of hearing, since we can feel the , emitted by the sun. Nor is it difficult to conceive of such an ease in the delicacy of the sense of touch that even the minute of heat received from the fixed stars might be felt, and so

Raising our eyes from the earth to regard the celestial objects, we find, in place of the indefinitely minute interval before considered, a really appreciable space of time occupied by light in carrying to us information as to the condition of those distant orbs. From the moon light takes little more than a second and a quarter in reaching us; so that we obtain sufficiently early information of the condition of our satellite. But light occupies more than eight minutes in reaching us from the sun; a longer or shorter interval in travelling to us from Mercury, Venus, and Mars, according to the position of these planets; from about thirty-five to about fifty minutes in reaching us from Jupiter; about an hour and twenty minutes on the average in speeding across the great gap which separates us from Saturn; while we receive intelligence from Uranus and Neptune only after intervals respectively twice and three times as great as that which light takes in reaching us from the ringed planet.

Thus, if we could at any instant view the whole range of the solar system as distinctly as we see

piter or Mars when in opposition, the scene pre-
nted to us would not indicate the real aspect of the
ar system at that, or indeed at any definite instant.
ecisely as a daily newspaper gives us a later account
what is going on in London than of events happen-
g in the provinces, of these than of events on the
ntinent, and of these again than of occurrences
king place in America, Asia, Africa, or Australasia,
the intelligence brought by light respecting the
rious members of the solar system belongs to dif-
ent epochs. If man had powers of vision enabling
n to watch what is taking place on the different
nets of the solar system, it is clear that events
the utmost importance might have transpired—
der his very eyes, so to speak—while yet he re-
ined wholly unconscious of their occurrence. Or,
invert the illustration, if an observer on Neptune
ıld see all that is taking place on the earth, he
ght remain for hours quite unconscious of an event
portant enough to affect the welfare of a whole
ntinent, though that event should happen under his
es, and his visual powers be such as I have sup-
ed. We can imagine, for example, an observer on
ptune watching the battle of Waterloo from the
ly dawn until the hour when Napoleon's heart was
full of hope, and our great captain was watching
h ever-growing anxiety, as charge after charge
eatened to destroy the squares on whose stedfast-
depended the fate of a continent. We can con-

to an intelligent Neptunian, and how eagerly he would have watched the manœuvres of either army, and also, what neither army knew of, the approach of Blucher with his Prussians. Yet, while our Neptunian would thus have traced the progress of the battle from his distant world, the conflict would in reality have been long since decided, the final charge of the British army accomplished, the Imperial Guard destroyed, Napoleon fugitive, and the Prussians, who to the Neptunian would be seen still struggling through muddy roads towards the field of battle, would have been relentlessly pursuing the scattered army of France.

It is, however, when we pass beyond the limits of the solar system that the non-contemporaneous nature of the scene presented to us becomes most striking. Here we have to deal not with seconds, minutes, or hours, but with years, decades, and centuries. From the nearest of the fixed stars light takes fully three years in travelling to the earth. Even the star 61 Cygni is so far from us that its light only reaches us in seven years. And so far as observation has hitherto gone, it seems unlikely that amid the whole host of heaven there are so many as a hundred stars—lucid or telescopic—whose light reaches us in a shorter interval of time than twelve or fifteen years. Whatever views we form as to the arrangement of the sidereal scheme, whether those usually accepted be held to be correct, or whether I have been right in adopting others, there can be no doubt that, amongst the stars revealed to us by the telescope, there must be myriads

ch lie many times farther from us than the bright
r in Centaurus and the orb in Cygnus which have
n found relatively so near. In fact, the views
ave adopted respecting the wide range of magnitude
ong the fixed stars do not interfere in the least
h the theories which have been formed as to the
tances from beyond which the light of some of the
rs, only just visible in powerful telescopes, must be
posed to reach us. On the contrary, one may con-
ve, according to my views, that some of these faintly
n orbs may be many times larger even than giant
ius, in which case the distance of such stars would
many times greater than has been hitherto supposed.
e may certainly assume with confidence that many
rs only visible in powerful telescopes shine from
yond depths which light would occupy thousands of
rs in traversing. I cannot, indeed, go farther, as
ronomers have hitherto done, and say that the
bulæ must be regarded as external galaxies, and
refore as sending their light to us over spaces
ich light must take many times as long an interval
traversing as it does in travelling to us from the
nds of our own galaxy. But it would be to mis-
erpret altogether the views which I have formed
pecting the universe to suppose that I imagine
se distant spaces which astronomers have hitherto
ed with imaginary galaxies to be untenanted. On
e contrary, I have no doubt whatever that galaxies
embling our own exist at distances infinitely ex-

most distant nebular universes, if even the bounds of our own galaxy do not extend into space as far as the widest limits hitherto assigned to the system of nebulæ. So that I am not precluded from speaking of orbs whose light, though unrecognised by us, is yet ever pouring in upon the earth, conveying, in letters we cannot decipher or even trace, a message which has taken millions on millions of years in traversing the awful gulf beyond which lie those mysterious realms.

If we conceive, then, that man's visual powers could suddenly be so increased that, without instrumental aid, he could look around him into the celestial depths, piercing even to those outer galaxies which astronomers have seen only imaged in the nebulæ, how wide would be the range of time presented to him by the wonderful scene he would behold! There would blaze out Alpha Centauri with its record three years old; there the star in Cygnus as it existed seven years since; the whole host of stars known to man would exhibit records ranging from a few years to many centuries in age; and lastly, the external galaxies, which are perhaps for ever hidden from the searching gaze of man, would reveal themselves as they were ages on ages before man appeared upon the earth, ages even before this earth was framed into a globe, nay, ages perhaps before the planetary system had begun to gather into worlds around its central orb.

It is when we are thus contemplating in imagination the whole expanse of the universe, and as one almost may say the whole range of past time, that the hor of the little treatise I have spoken of invites to consider two processes of thought having sole erence to this earth on which we live, and to that tory which, though all-important to ourselves, seems fade into such utter insignificance in the presence of grand history of the orbs which lie in uncounted lions around us.

To a being placed on some far distant orb, whence it would occupy thousands of years to wing its ht to us, there would be presented, if he turned his e upon our earth, and if his vision were capable of ing him of her aspect, the picture of events which usands of years since really occurred upon her face. For the light which left the earth at that ie, winging its way through space with the account, we may so speak, of those occurrences, is now tra- ling as swiftly as when it left our earth, but amid ions of space removed from us by a light-journey usands of years in duration. And thus, to the ob- ver on this distant orb, the events which happened in far-off years would seem to be actually in progress.

But now conceive that powers of locomotion com- nsurate with his wonderful powers of vision were en to this being, and that in an instant of time he ld sweep through the enormous interval separating n from our earth, until he were no farther from us n the moon. At the beginning of that tremendous rney he would be watching events which were urring thousands of years ago; at its close he would

ertook his instantaneous flight; so that, in the
of his journey, he would gaze upon a succession
ts which had occurred during those thousands
s upon the face of this little earth.

other conception is no less beautiful and striking
y remark, also, that it is, in a scientific sense,
at more exact. Suppose that a being armed
ch powers of vision as we have imagined should
from the neighbourhood of our earth the pro-
f some interesting event. If he then began to
rom the earth at a rate equal to that at which
avels, he would see one phase of the event con-
y present before him, because he would always
re the light-message recording that event was
y travelling. By passing somewhat less swiftly
e would see the event taking place with sin-
slowness; while passing away more swiftly,
ld see the event occurring in inverted order.
e, for example, he was watching the battle of
oo—he could gaze on the fine picture presented
Imperial Guard as they advanced upon the
n army, for hours, years, nay, for centuries or
or he might watch the whole progress of the
occurring so slowly that years might elapse
n each step of the advancing column, and the
which mowed down their ranks might either
nmoving, or else appear to wend their way with
y perceptible motion through the air; or finally,

life as the bullets passed from their wounds, until at
gth the Old Guard would be seen as it was when it
gan its advance, in the assured hope of deciding
aterloo, as it had already decided so many hard-
ght battles for its Imperial Chief.

It may seem hypercritical to notice scientific in-
ctness in ideas professedly fanciful. But as the
hor lays some little stress upon the scientific truth
he method in which his fancies are exhibited, and
further, he dwells upon two of the more obvious
ections to the first conception, it may be well to con-
er a further objection, which enforces on us a total
nge in the way of presenting the idea. He remarks
t the being he has conceived to be borne towards
earth through a distance so enormous would not
in a moment the whole history of the earth dur-
the thousands of years considered, but only the
tory of that hemisphere which was turned towards
n; while, further, all that took place under roofs or
der cover of any sort would remain unperceived by
n. But there is a more serious objection. Amongst
events which have taken place during those thou-
ds of years have been thousands of revolutions of
earth around the sun, and more than 365 times as
ny rotations of the earth upon her axis, to say
hing of the stately sway of the earth in her motion
precession. So that our imaginary observer would
reality see the earth whirling with inconceivable
pidity upon its axis, and sweeping with even more

nds of circuits in a single second. He would
ouds forming and vanishing in an amazing suc-
n of changes, all occurring in a single instant.
ven though his powers of vision enabled him to
the cloud-envelope, he would not have a conse-
presentment of the various events occurring in
art of the earth, but only a haphazard succession
f days for each portion of her surface.

owever, we can easily see that, by a slight modi-
n, the beautiful conception of our author can be
to illustrate one mode at least in which the events
ing upon our earth may be conceived to be at
nes present to the thoughts of an Omnipresent
. Imagine a sphere with a radius over which
would travel in the time which has elapsed since
creatures first began to move upon this earth,
aving for centre the place occupied by the
at that instant. Then, if we imagine millions
es over the surface of that sphere, all turned
piercing powers of vision upon the central earth,
e that to these eyes the earth would be pre-
by the record of light, not as she is now, but
e was at that primaeval day. Now, conceive
millions of eyes closing swiftly in upon the
but with this peculiarity of movement, that,
d of being always on a sphere around a fixed
they were always on a sphere around the posi-
hich was really occupied by the earth when the

cted in an instant, according to the law assigned it,
til its myriad millions of eyes were gazing intently
our earth from a sphere of but a few thousand miles
radius, the whole history of the earth, so far as light
uld render it, would have been in a moment of time
esented before the myriad-eyed sphere.

By extending these considerations to other modes,
which the history of an event is recorded, so to
eak, by natural processes, we can see that a much
ore complete and definite picture of past events than
ht can convey must be at all times present in the
iverse. A sense which could analyse heat-impres-
ons as eyesight analyses light, would tell us not
ly what eyesight tells us, but much that no light-
essages can convey to us. At least it is conceivable
at a sense of this sort would enable the being pro-
led with it to recognise not merely the nature of the
rface of any body whose heat reached the organ of
is sense, but the quality of the body's internal struc-
re, processes going on within the body, or the nature
bodies so placed that eyesight would not render us
nsible even of their existence. Electricity, in like
anner, would avail to give information altogether
stinct from that which light can impart.

But again, the senses by which we judge of what is
ing on around us are after all merely certain means
which we judge of causes by their effects. When we
y, for instance, that we have seen such and such an
ject, or watched such and such an event, what we

sions which we can only explain by the ex-
of that object, or by the occurrence of that
We know, in fact, that in certain exceptional
impressions resembling those caused by the
presence of an object, or by the actual occur-
of some event, may arise where no such object
en present, or where no such event has taken
till, we commonly feel safe from error in
ding from certain impressions conveyed to the
by the agency of the senses that certain objects
been really present, at rest or in action,
us.

t then, even man, limited as are his powers, can
llow a series of effects and causes far more
ous than those concerned in the act of vision;
he can become certain of the occurrence of past
of which no sense he possesses gives him any
information. For example, though I neither
e battle of Waterloo nor heard the thunder of
ns there, yet I am as certain that the battle
took place as though sight and hearing had
me direct information on the matter. And
I inquire whence that certainty arises, I find
plicated series of events involved in my acqui-
of the knowledge that the battle took place.
nterpretation of the letterpress account of the
involved in itself a number of more or less
ex relations, associated with the question of

ations of letters represented certain words, and
t certain words represented certain ideas. Not to
ow out the long train of thoughts thus suggested,
will be clear that, with regard to a variety of
tters, the knowledge which any man has is asso-
ed with considerations of cause and effect, of
eral experience, of confidence in the accounts of
ers or in his own judgment, which are in reality of
ighly complex character.

Now, we are led by these thoughts to remember that
ependently of those records of past events which
continually present throughout the universe in
cesses resembling those which directly affect our
ses, such events leave their record (even to their
utest details) in the consequences to which they
e led. If a great naturalist like Huxley or Owen can
by examining the tooth of a creature belonging to
e long extinct race, not only what the characteristics
hat race were, but the general nature of the scenery
idst which such creatures lived, we see at once that a
gle grain of sand or drop of water must convey to an
niscient and Omnipresent Being the history of the
le world of which it forms part. Nay, why should
pause here? The history of that world is in truth
nd up so intimately with the history of the universe
t the grain of sand or drop of water conveys not
y the history of the world, but with equal complete-
s the history of the whole universe. In fact, if we
sider the matter attentively, we see that there can-

attained its present exact position and state, had history of any part of the universe, however nificant, been otherwise than it has actually been, en the minutest degree.

urning from the past to the future, we must not e limited nature of our recognition of the course ture events prevent us from forming a just on as to the way in which the future is in a sense s present. We can judge of the past by its s, but we are almost utterly unable to judge of uture by its causes. Yet we cannot doubt that uture is present in its germs, precisely as the past esent in its fruits. It may be regarded in fact as y a peculiarity of man's constitution that the past re clearly present to his mental vision than the e. It is easy not only to conceive that the future he past should be equally present to intelligent ures, but to conceive of a form of intelligence ding to which past events would be obliterated the mind as fast as they took place, while the e should be as actually present as to the ordinary n mind the past is.

considering the Omniscient Omnipresent Being, ver, all questions of degree must be set on one The future must be absolutely and essentially nt to such a Being in its germs as the past has shown to be in its fruits. If a grain of sand con- in its state, figure, and position, the picture of the this is so ?—it contains with equal completeness the history of the universe throughout the infinite future. No other view is compatible with the assumption of infinite wisdom, and no assumption which limits the wisdom of a Ruler of an infinite universe is compatible with our belief in the fitness of such a Ruler to reign supreme over the universe.

Obviously also every event, however trifling, must be held to contain in itself the whole history of the universe throughout the infinite past and throughout the infinite future. For every event, let its direct importance be what it may, is indissolubly bound up with events, preceding, accompanying, and following it, in endless series of causation, inter-action, and effect.

So far, then, as the supervision of a Ruler over the universe is concerned, we have two lines of thought, each leading to the recognition of perfect supervision. In virtue (1) of the omnipresence, and (2) of the infinite wisdom of such a Ruler, He could see at each instant the whole universe as it has been in the infinite past, as it is now, and as it will be in the infinite future; and this being as true of any one instant as it is of any other, we recognise the operation of yet a new form of infinity—the infinite duration of the Ruler's existence —to render yet more inconceivably perfect His supervision of the universe.

With regard to control it need hardly be said that if a Ruler does exercise control, apart from the laws assigned to His universe, His knowledge of the procalled in question, since His own direct action, whether in the past or in the future, would be quite as much the subject of His consciousness (to use this word for want of a better) as the action of His creatures or of the laws He had primarily set them.

We know that certain laws have been assigned to the universe, and we know, also, that, so far as our very limited experience enables us to determine, these laws are never abrogated. Here I set altogether aside, for the moment, the possibility of miracles (since miracles would necessarily be non-natural events), and consider only the results of experimental or observational science. Thus we are led to the conclusion that all things happen according to set physical laws; and we see strong reason to believe that these laws are sufficient for the control of all things.

Now it seems conceivable that in reality it is only our limited acquaintance with the operation of the laws of the universe which makes us regard them as unchanging, and so to speak inexorable. But I think that this view—though it has been entertained by many thoughtful men—is in reality inconsistent with just conceptions of infinite wisdom. If the wisdom of a Ruler of the universe, though inconceivably great, were yet finite, we could not suppose that the universe would have been so planned (still to use inexact words for want of better), and laws of such a nature assigned to it, that throughout the infinity of time all things should work well. There would then, undoubtedly, be continual need of adaptation, change, d remodelling—of the annulment of a law here, or suspension there—in order that the whole might not l to wrack. But with a Ruler infinitely wise, there ould be no such necessity. The whole scheme of e universe would be so perfect that direct interven- on would not at any time be required.

To sum up, we perceive that, before a Ruler omni- esent, omniscient, and omnipotent, the infinite past d the infinite future of the universe would be at all nes sensibly present; that each the minutest atom d every the least important event would exhibit fore Him at each instant the perfect history of the nitless past and future of the universe; and lastly, at His infinitely perfect consciousness of, and con- ol over, all that has been, is, or will be, would be finitely multiplied (to use the only available expres- on) by the infinite duration throughout which His istence would extend.

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